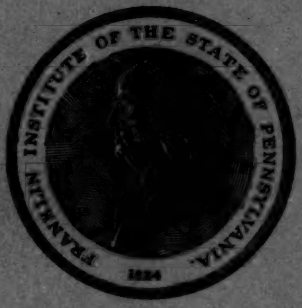
Journal
of
The Franklin Institute

AUGUST, 1952

1826  1952

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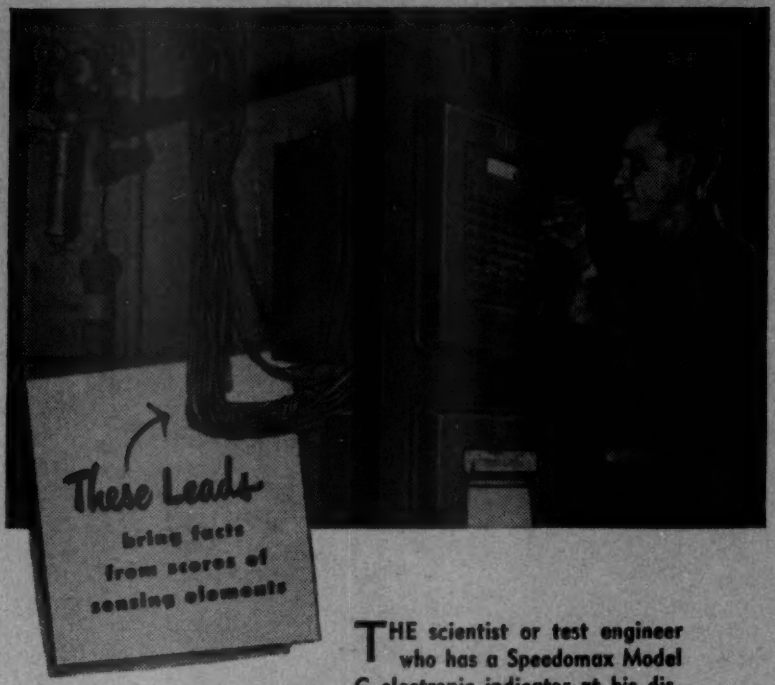

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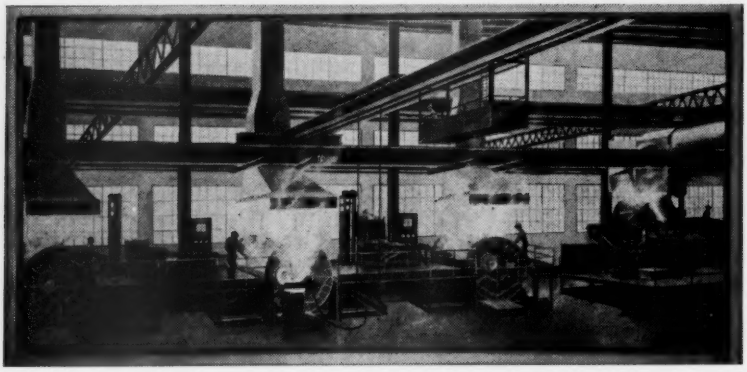

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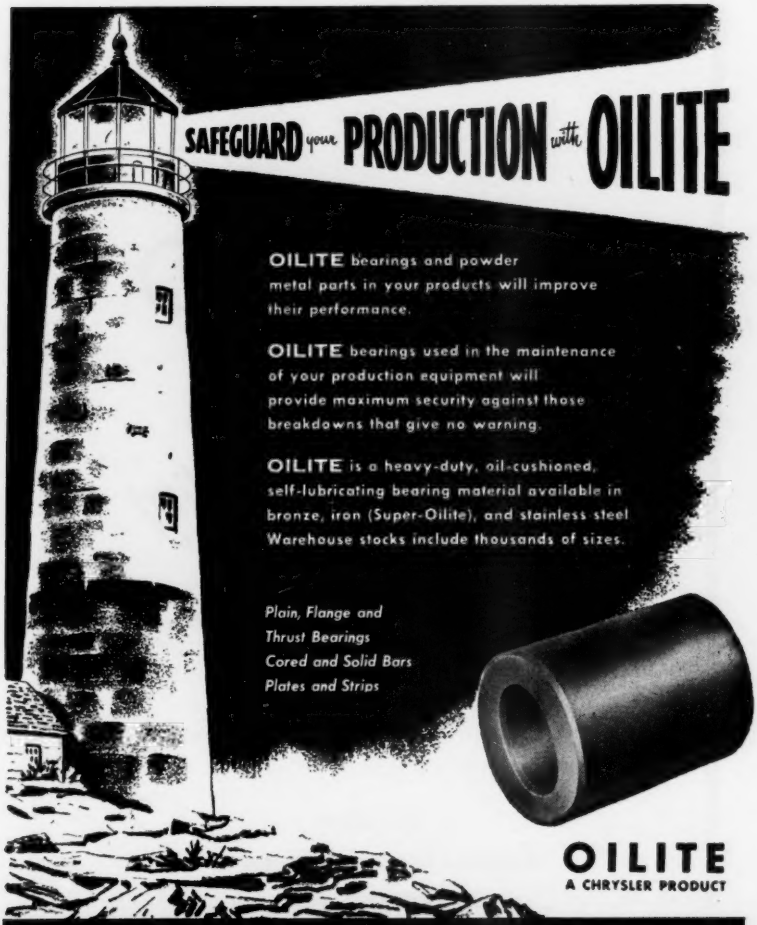
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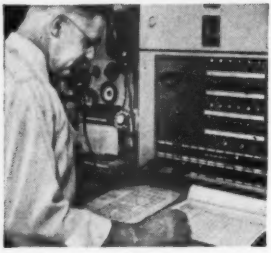

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Journal
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Vol. 254 AUGUST, 1952 No. 2

FRANKLIN'S WIT AND WISDOM *

BY

THOMAS COULSON [1]

When I was asked to address you upon the subject of the lighter side of Franklin's writings, I accepted with certain misgivings. It did not appear to me to be a happy choice for a speaker who comes from a race that is reputed to have no sense of humor. Then again, having had some distressing experiences with the performances of the professional comedians who are to be heard on radio and seen on television, I concluded there must be some racial deficiency in my sense of humor or that there was a distinctive national humor and that I failed to appreciate their particular brand. In any event I got very little joy out of the programs. Of course, I admit that may have been the fault of the comedians, for there is something rather pitiful in the efforts of a professional who must try deliberately to be funny. A feeling of pity may have dulled my humor.

Happily, Benjamin Franklin was not a professional humorist who was ever constrained to be funny at all costs, and even if there is a national sense of humor I do not believe he can be classed as an essentially American humorist, although there is a refreshing sense of gaiety in much of what he wrote. Perhaps it is wrong to think of Franklin as a humorist in spite of his many humorous sallies and asides. What, then, should we call him? To my mind he is best described as a wit.

Franklin is much more of a wit than a humorist, because humor is too often associated with nonsense, whereas wit walks hand in hand with wisdom. Was it not the genial old Cervantes who said, "Good wits jump; a word to the wise is enough"? There we have a clue to the lighter side of Franklin. His words were addressed, if not exactly to the wise, at least to those who wished to acquire wisdom. His wit was employed

* From the notes of a talk given to the Hostess Committee of The Franklin Institute, February 14, 1952.

[1] Director of Museum Research, The Franklin Institute, Philadelphia, Pa.

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to sharpen his wisdom, to give it point, and to impress it more clearly on the memory. We must remember that in his day there were not the numerous newspapers and digests which reproduce and broadcast pithy sayings. In those days more reliance had to be placed upon memory; a neat saying would be passed by word of mouth, so that the more easily it could be remembered the better chance it had of surviving.

Let us take for examples those familiar maxims in *Poor Richard's Almanac*, by which he is best remembered. Many of them were not original. Some were already proverbial in those days. The English almanacs, notably *Robin Goodfellow's*, made a practice of sprinkling maxims through their texts, but these were often quotations of rustic philosophy, often in dialect form, but nearly always expressed clumsily. Today, those maxims are read only by scholars and students of the eighteenth century literature of England. Franklin took these clumsy sayings, gave them a twist, or re-arranged the words in such manner that the sense remained but was expressed in more pungent form. What had been a heavy-handed piece of rustic philosophy sparkled brilliantly in a new dress and, what is equally important, it could be memorized without effort. These delightful fragments of philosophic wisdom, neatly expressed in a happy choice of words, passed into the mental currency of a people who would never have dreamed of trying to remember the laborious words in which the original thought was buried. Moreover, when Franklin made it easily quotable, he introduced that thought to millions of others who might have remained ignorant of it.

Now, this ability to give a "twist" to a phrase which made it memorable was not a natural gift. It was acquired after much toil to achieve a mastery over words. As a child, Franklin had aspired to become a poet under the inspiration of an uncle who was a voluminous writer of doggerel verse, but his sensible father had discouraged him, urging him to devote himself to the writing of prose. Franklin set about this task with remarkable thoroughness. He would read one of the essays in his precious copy of the *Spectator* and, when he had mastered its sense, he would paraphrase it into poetry. This in itself was an excellent exercise for a prospective writer, but it did not satisfy the perfectionist in Franklin. He would next take his poem and transpose it back into prose, avoiding as far as possible the words originally employed. These exercises gave him a rich vocabulary and a sensitive feeling in the use of words.

Anyone who has tried to do serious writing will know that it is possible to set down in correct grammar a sentence which will convey the writer's meaning, but it is quite another thing to make that happy selection of words which will make the phrases haunt the reader's memory. Further, a statement of fact can be so phrased that it not only conveys a truth but provokes a smile. It is not only the choice of words that makes the change, although that choice implies a mastery over

words and a skill in their application which is characteristic of the true master. The smile beneath the words must come from an inner source which is of the nature of the man himself.

A wise Frenchwoman, Madame de Stael, said, "Wit consists in knowing the resemblance of things which differ, and the difference of things which are alike." Franklin appears to have been fully conscious of this quality of wit, for many of the most popular quotations from his writings prove its truth. He wrote, for instance, "Glass, china, and reputation are easily cracked but never well mended." There you have a resemblance of subjects that are unrelated—glass and human reputation. But you see in their fragility and in their lack or restoration a striking resemblance. How otherwise could it be written in the same number of words so that it will remain an easily remembered phrase? Or, take another quotation from his work: "Men and melons are hard to know." The truth and the aptitude of those words are instantly apparent to anyone who has ever had to buy melons.

Another great writer of maxims, La Rochefoucauld, once said, "The greatest fault of a penetrating wit is to go beyond the mark." This is a fault from which Franklin was wholly free. He never went beyond the mark. Not a single ill-natured jest is recorded of him. If he felt that a reproof was called for he administered it as gently as possible, and removed its sting with a spice of wit. This can be illustrated by a story which, I believe, has not appeared in English.

One of his acquaintances who had prospered built himself a home and invited Franklin to inspect it. The entrance hall was so spacious that Franklin in surprise was moved to inquire why so much space had been wasted on it. "I can afford it," was his host's laconic reply. The drawing room was magnificant, although Franklin knew that his host rarely entertained, and he commented upon this, only to receive the same answer—"I can afford it." The dining table could seat as many as twenty-four people, and yet no more than six chairs were ever occupied. Franklin simply could not understand this sign of ostentation in his friend but to all his hints and questions he received the stolid assurance "I can afford it." The repetition of this answer nettled him, the luxury and the waste displayed by a man who was evidently proud of wealth offended his simple tastes, so that, when he was leaving he asked his host innocently, "Do you wear a hat ten times too big for your head?" The astonished host asked him what purpose there could be in such a folly. "You can afford to," answered Franklin, quietly proceeding on his way.

Franklin has left too many evidences of his dislike for display, luxury, and intemperance to leave any doubt about his feelings upon such matters. Only his unfailing good nature prevented him from placing pointed barbs on his wit when he spoke of some individual's surrender to luxurious living. His comments at such times were delivered so jovially that even the victim could join in the laughter and

continue to call Franklin his friend. None of his witty comments was vindictive and none caused pain.

Another pleasant tale was current in France, and appears to have escaped translation. This related to his life in London where he had made many friends who held his judgment in high esteem. Some of these men were of the aristocracy, men who appreciated his subtle mind and sober judgment, even if they did not follow his example of simple living. One of these friends, a wealthy nobleman, had built himself a new home on one of the narrow London streets. The front of this house was extraordinarily ornate, with rich carving and fine pillars. When Franklin visited the house he found much to admire in its exterior, but in order to obtain this fine effect the house had to be set back so far from the street that its interior suffered in conveniences. It would have been the easiest thing in the world for Franklin to have made some devastatingly witty comment upon the nobleman's love of exterior show, but he refrained. Having in mind the narrowness of the street in which the house stood, Franklin's only remark was that "All his lordship had to do in order to appreciate the beauty of his home was to rent an apartment on the other side of the street from which he could see its beauty."

Franklin as a writer is neglected. The *Autobiography*, of course, is highly popular, it is frequently republished, and must have been translated into every language that has a cultivated literature. But why is it read? Is it not so that the reader may learn something about the man himself? Readers come to know him as a printer, a scientist, and a diplomat, but the book is too little read for its intrinsic literary merit. His writing always seems to be subordinate to his other accomplishments. What I should like to see is a more popular approach to the writings themselves. You might shrink from reading through the voluminous collected works, and I would not blame you since I have never been able to do that myself, but in *A Franklin Reader* (Crowell, New York, 1945) and in *Satires and Bagatelles* (Fine Book Club, Detroit, 1937) you will find a selection of writings which furnish rewarding reading.

Here you will find a graceful, simple style, unadorned by purple patches but flowing as freely as dry sand. He always has something to say and says it with a singularly appropriate choice of words. Unless he is writing upon some subject which calls for gravity and restraint, you will find that the good natured, light hearted side of the man is constantly revealed. In his letters and papers you will find an unfailing current of playfulness and a tendency to drollery which is much more like a personal conversation than a piece of studied writing. Read him in his more informal moods, in his letters, in the delectable papers he wrote for his friends, and you will find yourself drawn into the incomparable charm of a man whose indulgent laughter at human foibles explains his universal popularity in spite of his being a moralist.

A YIELD CRITERION FOR DUCTILE METALS BASED UPON ATOMIC STRUCTURE

BY

MILTON C. SHAW [1]

ABSTRACT

A strength theory for ductile metals is presented that takes into account the short range inhomogeneities that are present in all commercial metals. Examples are presented to illustrate the shortcomings of the conventional maximum shear stress and distortion energy theories that result from the failure of these theories to recognize the inhomogeneous nature of metals. The new theory predicts a variation in yield stress with specimen size and it is shown why such a size effect is observed with torsion specimens but not with tensile specimens of usual size. The size effect in fatigue testing and hardness testing by means of micro techniques is discussed to illustrate further the concepts presented. Finally, the relation of the new theory for ductile metals to the statistical theory of Weibull for brittle materials is considered.

INTRODUCTION

The general field of stress analysis has been continuously developed over a period of many years until today it is among our most precise engineering subjects. One of the more important considerations in this field has to do with the manner in which one stress configuration is interpreted in terms of another. These rules of comparison are frequently referred to as strength theories,[2] or yield criteria and a great many such rules have been proposed in the past for ductile metals. While most of these criteria have long since been discarded, two of them have stood the test of time. These are the distortion energy and the maximum shear stress theories (1).[3]

According to the maximum shear theory a member will yield when the maximum shear stress in the body is equal to the maximum shear stress in a tensile member that is loaded to the yield point. On the other hand, the distortion energy theory states that a member will yield when the effective stress σ_e, given below, is equal to the principal tensile stress for a tensile specimen loaded to the yield point.

$$\sigma_e = \frac{1}{\sqrt{2}}\left[(\sigma_1 - \sigma_2)^2 + (\sigma_2 - \sigma_3)^2 + (\sigma_3 - \sigma_1)^2\right]^{\frac{1}{2}}, \qquad (1)$$

where σ_1, σ_2, and σ_3 are principal stresses. While each of these rules gives results that are in fairly good agreement with experiment, one of

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[2] While the term "strength" theory might be reserved for a criterion concerned with the fracture of materials it is also frequently used in connection with the yield stress. It is in this latter broader sense that the term strength theory is used here.

[3] The boldface numbers in parentheses refer to the references appended to this paper.

them will usually appear superior to the other. An item that is common to both of these concepts is the assumption that the material involved is homogeneous. However, there is considerable evidence in our experience with materials that indicates that metals do not behave in a homogeneous fashion. It will be shown in this paper how this observed lack of homogeneity gives rise to a size effect in materials testing, and a theory of strength will be presented which includes the influence of the sort of inhomogeneity that is present in ductile metals.

INDICATIONS OF THE INHOMOGENEITY OF METALS

From X-ray diffraction studies it has been clearly established that metal structures consist of orderly arrays of ions that are closely packed. The ions are subjected to repulsive and attractive forces which dictate their mean equilibrium positions, and by way of an analogy it is convenient to regard the ions as closely packed, semi-rigid spheres. A consideration of the manner in which interionic forces vary with displacement indicates that the large deformations that are observed in metals must result from a process in which one row of ions is caused to glide across another. Such a glide process is usually referred to as slip.

The yield point that should be expected for a perfectly homogeneous metal may be estimated from a relatively simple calculation based upon the foregoing picture. In Fig. 1 two neighboring rows of ions adjacent

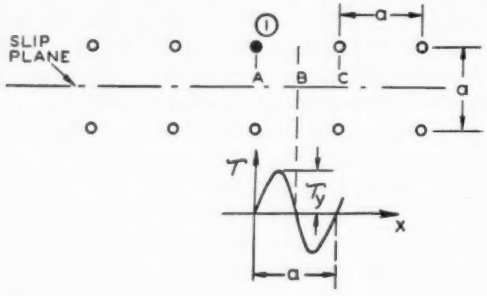


FIG. 1. Variation of shear stress with displacement for a metal having a perfect lattice.

to a slip plane are shown, the spacing of ions in the horizontal and vertical directions being a. If attractive and repulsive forces are balanced in the position shown, then equilibrium will also obtain when ion (1) occupies positions B or C. That is, the stress required to maintain the upper layer of ions with ion (1) at A, B, or C will be zero. When ion (1) is between A and B all atoms in the upper row will be subjected to attractive forces and a positive shear stress will result, while when ion (1) is between B and C a negative shear stress will

exist. If we assume a sinusoidal variation of stress with displacement, then

$$\tau = \tau_y \sin \frac{2\pi x}{a}, \tag{2}$$

where

τ_y is the maximum shear stress,
x is the displacement of one row relative to the other, and
a is the ion spacing.

For a small displacement x, the sine of the angle $\frac{(2\pi x)}{a}$ may be replaced by the angle in radians, and Hooke's law in shear will hold:

$$\tau = G\gamma = G\frac{x}{a}, \tag{3}$$

where G is the shear modulus and γ is the shear strain. Hence, from Eqs. 2 and 3 we find that

$$\tau_y = \frac{G}{2\pi}. \tag{4}$$

This indicates that the yield stress for a perfectly homogeneous metal should be approximately equal to the shear modulus divided by 2π. For steel this amounts to about $\frac{11.5 \times 10^6}{2\pi} = 1.8 \times 10^6$ psi. However, the observed yield stress for mild steel is actually found to be about 30,000 psi. (that is, 1/60 times the theoretical value). This difference between observed and expected yield stress should lead us to suspect that metals are not really perfectly homogeneous as assumed.

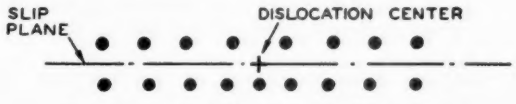


FIG. 2. Configuration of ions in a dislocation.

The dislocation (Fig. 2) is the ion lattice inhomogeneity that is now believed responsible for the discrepancy between the observed and theoretical yield points. In the ion configuration shown in Fig. 2 the spacing in the upper row is locally different from that in the lower row, and hence when one row tends to slip past the other, some of the ions are subjected to a net attractive force while at the same time others are in a position to experience a net repulsive force. The stress required to cause the dislocation to move across the crystal is, therefore, much less than in the case of a perfect lattice arrangement. While at present it is not certain whether dislocations are generated at points of stress

concentration in a metal as rapidly as they are required to provide the necessary strain or whether the dislocations that may be initially present generate others under an applied stress by some sort of breeding mechanism, this particular detail need not concern us here. In either case we may broadly say that the slip which occurs is associated with inhomogeneities that are present in the metal. A displacement of one atom spacing of the upper row of ions relative to the lower row results when a dislocation has passed clear across a crystal. Hence, the passage of a great many dislocations is involved in the deformations that are observed in metals.

When a tensile specimen that has been subjected to plastic deformation is examined, lines may frequently be seen on the surface which mark the slip planes. Such lines are sometimes referred to as Lüder's lines. When a replica of a deformed metal surface is examined

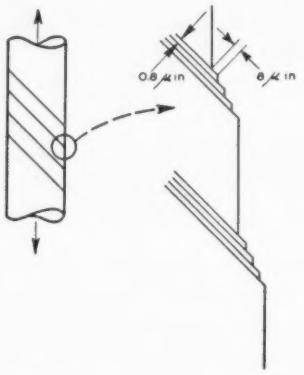


FIG. 3. Spacing of slip planes in an aluminum single crystal.
(Based on data of Heidenreich and Shockley (2).)

at very high magnification by means of the electron microscope individual slip lines are evident as shown in Fig. 3. In such studies Heidenreich and Shockley (2) have found that slip does not occur on all atomic planes, but only on certain discrete planes. In experiments upon deformed aluminum single crystals the minimum spacing of adjacent slip planes was found to be approximately 0.8μ in. (about 50 atomic planes) while the mean slip distance along these active slip planes was found to be about 8μ in. (about 500 atom spaces). These experiments further support the observation that metals are not homogeneous and suggest that the planes along which slip occurs are associated with the inhomogeneities in the metal.

There are occasional references in the literature to an increase in the strength of a metal with decreasing specimen size. Such observations have most frequently been associated with the tensile strengths of very

fine wires. While the observed high strength of fine wires has generally been discounted by attributing it to additional strain hardening associated with the drawing of such fine wires, recent experiments in metal cutting (3) have demonstrated that a size effect actually exists for ductile metals. These tests were not clouded by the strain hardening issue. It was found that as the size of the specimen (chip thickness) was decreased the shear stress to produce the required shear strain increased continuously until the theoretical strength was actually reached in the fine grinding operation (Fig. 4).

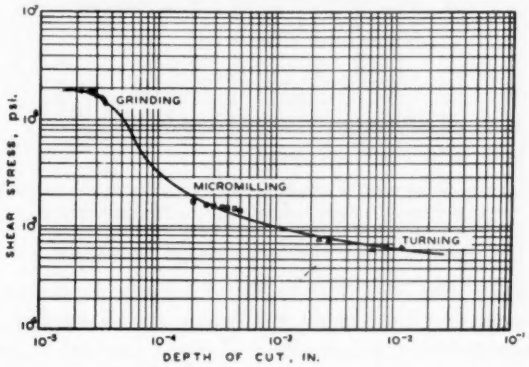


FIG. 4. Variation of shear stress in cutting with depth of cut, SAE 1112 steel (ref. 3).

A COMPARISON OF TENSILE AND TORSION DATA

The nature of the difficulty that is experienced with current yield criteria may be illustrated by some data due to Morrison (4), who carefully performed tensile and torsion experiments upon geometrically similar specimens of mild steel of varying diameter. In Table I results are shown for bars of 1-in. and $\frac{1}{8}$-in. diameter. Here the quantity q refers to the yield stress of the steel in torsion while f denotes the yield stress in tension. According to the maximum shear theory

TABLE I.

Specimen Diameter, in.	Yield Stress in Tension, tons/sq. in. f	Yield Stress in Torsion, tons/sq. in. q	q/f
1	22.70	12.05	0.530
$\frac{1}{8}$	22.94	13.91	0.607

the ratio q/f should be 0.5 and according to the distortion energy criterion it should be $1/\sqrt{3} = 0.577$. It is evident that a person performing his tests upon 1-in. bars might have more enthusiasm for the maximum shear theory, whereas someone working exclusively with $\frac{1}{8}$-in. diameter bars might champion the distortion energy theory.

All of Morrison's experimental points of this sort are shown in Fig. 5. Here it is clear that any correlation between the test results and either of the current strength theories is merely a matter of a fortuitous choice of specimen diameter.

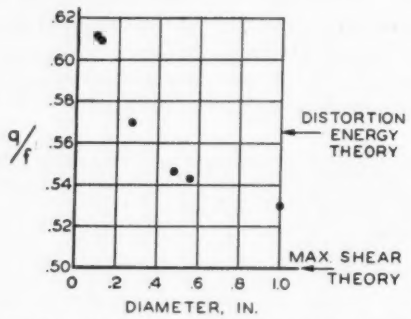


FIG. 5. Variation of the ratio of torsional yield stress (q) to tensile yield stress (f) with specimen diameter. (Data due to Morrison (ref. 4).)

THE QUANTIZED THEORY OF STRAIN HARDENING

The difficulty that is evident in Fig. 5 may be explained in terms of the inhomogeneities that are characteristic of all engineering metals. The previously mentioned size effect that is observed in metal cutting has been explained in a recent paper (5). Here it was proposed that small, closely spaced inhomogeneities are distributed throughout ordinary metals, and are responsible for the spacing of the individual planes of slip, there being one inhomogeneity per slip plane. The strain energy that is involved in deformation is considered to be associated with these discrete planes and not uniformly distributed through the metal according to the usual picture. Due to strain hardening, the stress corresponding to a given strain will increase as the spacing of the individual planes increases. The fact that all possible slip planes are not active and that the strain energy associated with deformation is not uniformly distributed but is concentrated on certain discrete planes that are active, suggests the name of this theory.

APPLICATION TO TENSILE AND TORSION DATA

If we now apply the foregoing picture to the tensile and torsion tests already mentioned, we will see that the data of Fig. 5 are really what might be expected from our strength theories if properly applied. Consider a layer of thickness t near a free surface in a metal that is loaded in tension (Fig. 6). A uniform array of inhomogenities is assumed as shown on this specimen at a spacing a. The two planes intersecting inhomogeneities A and B are spaced normally a distance $(a \sin \phi)$, and there will be $(t/a - 1)$ additional slip planes which lie between planes A and B if we assume but one active slip plane per

inhomogeneity. Thus, for a layer of depth t, the average spacing of adjacent slip planes will be $(a \sin \phi)$ (a/t) and from the definition of shear strain the total slip on a given plate will be

$$x = \frac{a^2 \sin \phi}{t} \gamma. \tag{5}$$

Now practically all engineering metals exhibit the phenomenon known as strain hardening when strained at room temperature. That is the mean flow stress is observed to increase as the shear strain increases. For most materials this variation of stress with strain is

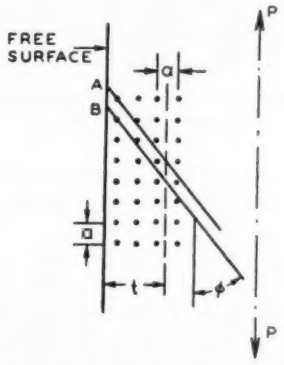


FIG. 6. Tensile bar with uniform array of inhomogeneities.

approximately linear. Since the elastic region of the stress-strain curve is usually of negligible extent relative to the entire curve we may approximate the stress-total strain curve for an active slip plane by a straight line of slope A as shown in Fig. 7. Hence, the stress corresponding to the strain per plane given by Eq. 5 will be

$$\tau = \tau' + Ax = \tau' + \frac{A(a^2 \sin \phi)}{t} \gamma. \tag{6}$$

To bring a layer of metal of depth t to the yield point and produce a definite yield strain γ_y will, therefore, require a stress

$$\tau_y = \tau' + \frac{Aa^2 \sin \phi \gamma_y}{t}, \tag{7}$$

where τ' is the bulk yield stress for a layer of infinite thickness and τ_y is the yield stress for the layer of thickness t. Now, for a given metal A, a, ϕ, and τ_y will be constant and hence we may write

$$\tau_y = \tau' + \frac{k}{t}, \tag{8}$$

where k is a constant.

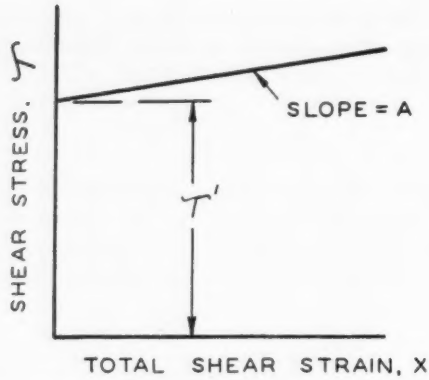


FIG. 7. Variation of plastic flow stress on a single shear plane with the total strain on this plane.

The meaning of Eq. 8 may be illustrated by reference to Fig. 8. Here the curve of Eq. 8 is shown plotted to scale on a structural member that may be loaded in any complex manner. If the metal in the layer of thickness t_A extending from A to the surface is the first to yield, then flow will just occur when the stress at point A reaches the value τ_A which is the value obtained by substituting t_A for t in Eq. 8. On the other hand if the more extensive region extending from B to the surface would tend to yield initially and all at once, then the yield stress in this instance would be the lesser value τ_B.

In Fig. 9 tension (*a*) and torsion (*b*) specimens are shown, and the solid curves again represent the shear stress that must be developed in a layer of thickness t in order for it to yield. As already explained a stress equal to τ_1 is required to cause a layer of thickness t_1 to yield.

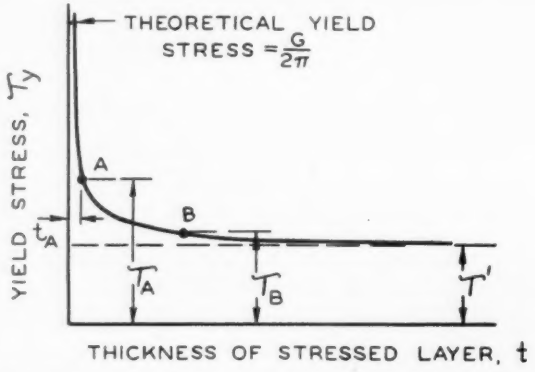


FIG. 8. Variation of yield stress with thickness of stressed metal layer.

The dotted lines show the manner in which the stress develops across the section with increasing external load. When the dotted line touches the solid curve, yield will occur in the layer extending from the point of tangency to the free surface. It is evident from Fig. 9 that torsion specimens are more sensitive to specimen size than tensile specimens. While the quantity q is as shown in Fig. 9*b* (the stress corresponding

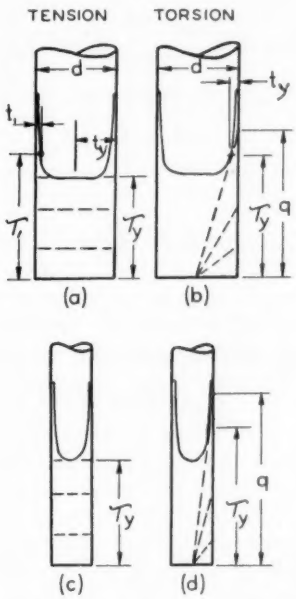


FIG. 9. Tensile and torsion specimens of different size.

to the point where the inclined dotted line intersects the free surface) it is evident that the true yield stress is less than this and equal to τ_y.

If now the maximum shear theory is used in conjunction with the foregoing size effect, then from Fig. 9*a*

$$f = 2\tau_y = 2\left[\tau' + \frac{k}{\frac{d}{2}}\right]; \tag{9}$$

from Fig. 9*b*

$$q = \left[\frac{\frac{d}{2}}{\frac{d}{2} - t_y}\right]\left(\tau' + \frac{k}{t_y}\right); \tag{10}$$

and from Eq. 8 and Fig. 9*b*

$$\frac{d\tau_y}{dt_y} = -\frac{k}{t^2_y} = -\frac{q}{\frac{d}{2}}. \tag{11}$$

Eliminating t_y between Eqs. 10 and 11 and expressing the resulting equation in non-dimensional form we have

$$Q = \left[\frac{1}{1 - \sqrt{\frac{K}{Q}}}\right](1 + \sqrt{KQ}), \tag{12}$$

where

$$Q = \frac{q}{\tau'}$$

$$K = \frac{2k}{\tau' d}.$$

Solving Eq. 12 for Q

$$Q = [\sqrt{K} \pm \sqrt{K + 1}]^2. \tag{13}$$

Expressing Eq. 9 in non-dimensional form we have

$$F = 2(1 + K) \tag{14}$$

where

$$F = \frac{f}{\tau'}.$$

From Eqs. 13 and 14

$$\frac{Q}{F} = \frac{q}{f} = \frac{[\sqrt{\quad} \pm \sqrt{K + 1}]^2}{2(1 + K)}. \tag{15}$$

However, since $K \ll 1$ but $K^{\frac{1}{2}}$ is not negligible relative to unity, Eq. 15 may be expressed as follows to a good approximation.

$$\frac{q}{f} = \frac{1}{2} \pm \sqrt{K}. \tag{16}$$

The positive sign is the only one of physical significance, and hence

$$\frac{q}{f} = \frac{1}{2} + \sqrt{\frac{2k}{\tau' d}} = \frac{1}{2} + \frac{\text{constant}}{\sqrt{d}}. \tag{17}$$

If the values of τ' and k for the steel of Fig. 5 are taken as follows

$$\tau' = 11.35 \text{ tons/sq. in.}$$

$$k = 0.006 \text{ tons/in.},$$

then the constant in Eq. 17 is 0.0325 $(\text{in})^{-\frac{1}{2}}$, and the solid curve shown in Fig. 10 is obtained. This curve is seen to be in much better agree-

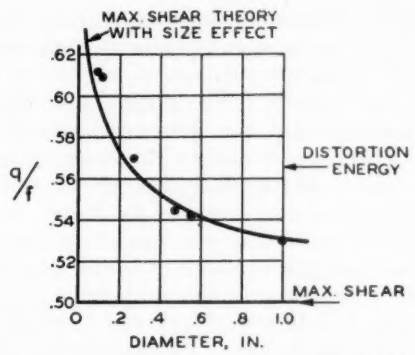


FIG. 10. Comparison of maximum shear theory including size effect with the experimental points of Fig. 5.

ment with the experimental points than either the conventional maximum shear or distortion energy theories. It is seen that the maximum shear theory is in good accord with the experimental data only when the size effect which results from inhomogeneities in the steel is included in the analysis. While the distortion energy theory could be altered in a similar way to take into account the size effect, it does not appear worth the effort imposed by the more complex computations, in view of the questionable benefits to be derived.

In Fig. 9 it is evident that the size effect will be more significant in torsion tests than in tensile tests in the same size range. This fact is illustrated by the values given in Table II which were computed by the foregoing method using the constants for the steel of Figs. 5 and 10. There is seen to be a 13 per cent increase in the torsional yield point in going from a 20-in. diameter to a $\frac{1}{8}$-in. diameter specimen, while the corresponding change in tensile yield point, will be but 0.8 per cent. We can, therefore, conclude that the tensile yield point is unaffected by specimen size down to about 0.1-in. diameter, whereas the torsional yield point will be influenced by specimen size in specimens even above 1-in. diameter. From the foregoing discussion, it is evident that a tensile test is a poor choice if it is desired to study the size effect. For example, in order to achieve the theoretical strength $G/2\pi$ in a tensile

TABLE II.

Diameter, in.	Yield Point q tons/in.^{2}	% Increase	f tons/in.^{2}	% Increase	t_y, in.
20	11.45	—	22.701	—	.073
1	11.92	4.1	22.724	0.1	.016
$\frac{1}{2}$	12.13	5.9	22.748	0.2	.012
$\frac{1}{8}$	12.95	13.1	22.892	0.8	.006

test of Morrison's steel, a specimen diameter of about 15μ in. in diameter would be required, as may be seen by substituting this value of theoretical yield stress for T_y in Eq. 9.[4]

The value of t_y in Table II is the thickness of the layer in which yield first occurs in a torsion test. Direct evidence that torsion specimens actually first yield in a relatively thin surface layer as predicted by the foregoing theory, rather than throughout as in the case of a tensile specimen is presented in a paper by Read, Markus, and McCaughey (6). Here a bar of steel was loaded to the yield point very rapidly—in fact so rapidly that the strain in the thin surface layer was essentially adiabatic producing a high temperature, then an allotropic phase transformation, and finally a very rapid quench as heat flowed from the surface layer into the bar. This resulted in a thin layer (0.007 in.) of untempered martensite at the surface of the bar. The martensitic layer is clearly evident in Fig. 8 of ref. (6) and attests the fact that yield in torsion occurs at the surface rather than throughout the specimen as in the case of a tensile test.

OTHER APPLICATIONS

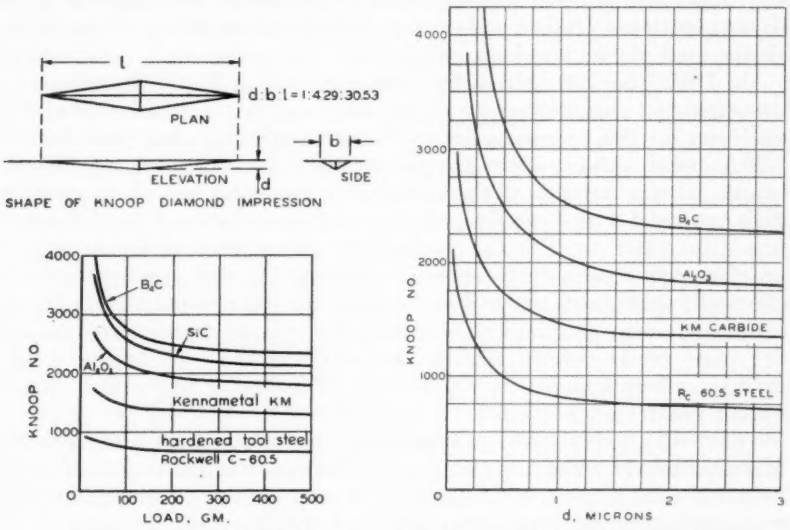
Many other applications may be made of the foregoing principles and a few of these will be briefly discussed. Any specimen that is subjected to a stress gradient across its section will be as sensitive to specimen size as the previously considered torsion specimen. For example, in the rotating beam fatigue test a linear stress gradient obtains and it is, therefore, not surprising to find in the range of specimen diameter from 1 to 0.1 in., a significant size effect. Jackson and Grover (7) have reported that the smaller specimens have from 15 to 20 per cent greater endurance limit than the larger ones in this range of specimen size. Wiegand (8) has also reported a size effect in fatigue tests that involve a stress gradient across the section of the test specimen. For example, it was found in one series of torsional fatigue tests upon a chrome-nickel-tungsten steel that the fatigue strength increased 40 per cent when the specimen diameter was varied from 1.4 in. (35 mm.) to 0.6 in. (15 mm.).

Notch-impact and bend tests will also show a pronounced size

[4] Equations 7 and 8 should not be expected to yield precise results when applied to layers of material of such thinness, since in their derivation a statistically mean picture was assumed. The yield stress, the angle of slip (ϕ), and the spacing of the inhomogeneities (a), were assumed to be the same at all points in the metal. While such assumptions are justified for layers of relatively large thickness compared with the spacing of inhomogeneities, the statistical distribution of the inhomogeneities should be taken into account for very thin layers. When this is done the yield stress is found to approach the theoretical value more rapidly than the analysis presented here would indicate. This means that the actual diameter to achieve theoretical strength is probably greater than 15μ in. Nevertheless, this value is seen to be of the same order of magnitude as the experimentally determined layer thickness required for theoretical strength in cutting, which was found to be about 30μ in. (see Fig. 4 of this paper, which is from ref. 4).

effect and may be handled just as the torsion test as long as the specimens are tested in a range where they behave ductilly.

Hardness testing by micro methods is another field in which a size effect is important. For example, in Knoop hardness tests (9) it is found that the indicated hardness of a hard specimen increases as the load on the diamond indentor is decreased. This is illustrated by the data of Fig. 11 where the Knoop hardness number is shown plotted



(*a*) Variation of hardness with load. (*b*) Variation of hardness with depth of impression, *d*.

FIG. 11. Knoop hardness values for several hard materials. (Data from Thibault and Nyquist (Ref. 10).)

against the indenting load for several hard materials. The shape of the indentor is also shown in this figure and the hardness number is the load divided by the projected area of the indentation. The data of Fig. 11*a* are shown replotted in Fig. 11*b* against the depth of the impression. These latter curves are seen to strongly resemble Fig. 8 and it would appear that the apparent increase in hardness with decreasing indenting load is actually due to the greater flow stress that accompanies a decrease in thickness of the deformed zone.[5] The size effect in hardness testing using the Knoop indentor is seen to about disappear when the depth of penetration of the indentor is about 2 microns ($= 80\mu$ in.). While the actual depth of the deformed layer is not known it is probably 2 or 3 times this value.

[5] These data were obtained in the conventional way and have not been adjusted for any possible visual discrepancy associated with the optical measuring system such as that described by Tarasov (11). The effect of such a correction would be to decrease somewhat the increase in hardness with decreased depth of impression, but the exact amount is not accurately known.

In the past the increase in hardness with decreased penetration has been generally ascribed to an elastic after-effect. While such an elastic effect might be expected to alter the *depth* of the impression observed when measured under load and unloaded, it would seem that this discrepancy would be negligible in the plane of the surface where the size of the indentation is actually measured in the case of the Knoop test. There are two experiments available in the literature which at first appear to support the existence of an elastic recovery effect, in Knoop hardness testing. However, careful examination of the techniques used place them in question.

In 1945 Tate (12) indented a glass plate with a Knoop indentor and measured the major diagonal of the diamond at the surface while the load was on the specimen, by looking through the glass from below. When these values were compared with the unloaded impression lengths, it was found that the unloaded values were less by an amount that increased with load (for a 68.7μ reading under load the difference was 4.5μ while for a 90.8μ reading the difference was 5.4μ). These are just the results that would be expected if the glass plate were elastically deformed under load. Since the plate would have to be supported as on an annulus in order to be able to observe from below, the plate could deform slightly and the resulting diffraction would produce a lens action that would tend to make the impression length appear greater under load.

The other experiment was described by Brodie and Smoluchowski in a discussion to Tate's paper (12). These experimentors coated their diamond with graphite before making an impression and then proceeded to measure the resulting impression and the length of the zone of removed carbon following the hardness test. The length of the zone of removed carbon was greater than the length of the hardness impression and this was again offered as evidence for an elastic recovery effect. However, when the diamond is removed from the surface following an impression, carbon will be pulled from the diamond from points beyond the actual level of penetration due to an electrostatic effect. This may be readily demonstrated by depositing a layer of carbon black of known thickness on a glass plate and then rolling a steel sphere of known diameter across the surface. When the track width is measured it is found to be significantly larger than would have been expected from the film thickness and ball diameter. The excess track width is due to the carbon, that is actually removed as a result of contact with the spherical metal surface, dragging additional material with it.

It is important to recognize the existence of the size effect in hardness testing and to take cognizance of its presence in the interpretation of hardness data obtained by micro-techniques.

There are still other places where the size effect is important. It accounts for the fact that thin layers of copper brazing metal (0.001

to 0.003 in. thick) have a shear strength that is about 2.5 times the shear strength of the braze metal in bulk (13). This concept should also be employed in the development of friction theory in connection with the real area of contact. Bowden and Tabor (14) are led to certain unreasonable conclusions by assuming that the yield stress of the very small asperities on sliding surfaces have the same yield stress as the metal in bulk. The application of the size effect concept in the fields of friction and wear has so many possibilities it appears advisable to defer this discussion to a later paper. However, there is one example in this general area that provides a striking verification of the existence of a size effect. This is an experiment described by Moore (15) in which he pressed a hard cylinder into a copper surface that had just been ruled with grooves about 7 microns deep (280μ in.). Even though the cylinder was forced 200 microns (8000μ in.) into the surface, the lower portions of the fine rulings were still evident. Here it is seen that the metal of the small projections has a greater yield stress than that of the metal in bulk.

While relatively little has been here mentioned regarding the important role that the size effect plays in metal cutting, this topic has already been covered in some detail elsewhere (3, 5).

BRITTLE FRACTURE

As indicated in the title of this paper, the theory of strength presented here is only for use with metals that behave in a ductile fashion. Glass, minerals and even steel at very low temperatures are usually classified as being brittle on the basis that they react differently to stress than ductile materials. A truly brittle material will remain elastic until stressed to the point of rupture. Such materials fail by the formation and propagation of a crack across the specimen. The theory of Griffith (16) which states that a crack will propagate when in so doing the accompanying decrease in strain energy is greater than the resulting increase in surface energy is the usually accepted criterion for determining the dimensions of a dangerous (unstable) crack in a brittle material.

The size effect that is observed in brittle materials is explained by Weibull's statistical theory (17). This theory is concerned with the probability of finding a crack or stress concentration of a certain intensity in a given specimen, and may be illustrated as follows in its simplest form. If σ is the rupture stress of a specimen without any cracks or internal stress concentrations, σ_0 the corresponding stress when one or more cracks of a given intensity are present in the specimen, and n the number of such cracks per unit volume, then the probability of finding a specimen of volume V that is crack-free is e^{-nV}. The statistically expected rupture stress for any specimen is then

$$\bar{\sigma} = \sigma e^{-nV} + \sigma_0(1 - e^{-nV}) = \sigma_0 + (\sigma - \sigma_0)e^{-nV}. \qquad (18)$$

From this expression it is evident that the average strength of a specimen will increase as its size (and hence volume, V) is decreased.

As previously mentioned we should not expect a significant size effect for ductile tensile specimens greater than 0.1-in. diameter. This is in agreement with the theory presented here which attributes greater yield strength to surface layers than the metal in bulk. Since a tensile specimen yields throughout rather than only at the surface there is no size effect until the diameter becomes so small that what might be considered the surface layer extends to the center of the specimen. However, from Eq. 18 we should expect a size effect for brittle specimens even when tested in tension, since the size effect then depends on the volume of the specimen rather than upon surface effects. The presence of a size effect in brittle tension is illustrated by tests of Davidenkov, Shevandin, and Wittmann (**18**) on mild steel at the temperature of liquid air. Even though no size effect was evident in tensile tests at room temperature with their steel, an increase in the brittle tensile strength of 30 per cent was noted in going from 10- to 1-mm. diameter (0.4 to 0.04 in.) at the temperature of liquid air.

While most fatigue failures are along a plane of maximum normal stress, on a macroscale, indicating a tensile type failure, McClintock (**19**) has clearly shown them to be shear failures on a micro-scale. Fatigue cracks zig-zag from crystal to crystal, the direction at each point being along a plane of maximum resolved shear stress. Thus, Weibull's size theory should not be applied to fatigue tests, but the theory for ductile materials presented here should be used instead.

Although the materials of Fig. 11 are generally classified as being brittle, they obviously behave in a ductile manner in the Knoop hardness test. This may be considered another consequence of small specimen size. According to Weibull's statistical theory the probability of finding a flaw decreases as the specimen size is decreased. If the volume deformed is very small as in the case of a Knoop impression there is reasonable probability of achieving the necessary plastic flow before rupture occurs. Actually, hard materials such as boron carbide frequently rupture when being indented. The very high compressive stress that is present when a material is indented will tend to prevent any very small cracks in the flow area from causing brittle fracture. Bridgman (**20**) has shown that many minerals and normally brittle substances become ductile when subjected to very high hydrostatic pressures. For example, sapphire (Al_2O_3) that is ordinarily brittle at atmospheric pressure, even at temperatures to within 50 C. of its melting point (2000 C.), becomes quite ductile when subjected to a hydrostatic pressure of 400,000 psi. However, inasmuch as glass and cemented carbides are not at all ductile in bulk even at pressures as high as 800,000 psi., yet may be indented without brittle fracture by a Knoop diamond indicates that the ductile nature of these materials in hardness testing by micro techniques is not alone due to

the high pressures involved. The size of the impression is also important. This observation is further supported by the fact that the harder materials cannot be indented at all by the larger indentors of conventional hardness tests without fracturing the specimen.

CONCLUDING REMARKS

In the past the existence of a size effect has been more or less generally recognized for brittle materials and has been satisfactorily explained by the crack concept of Griffith and the statistical theory of Weibull. However, the existence of an analogous effect for ductile materials has not been generally accepted or understood (for example, see ref. (21) p. 190–191). Recent experiments in the field of metal cutting, where a size effect is very pronounced, have focused attention upon the influence of specimen size upon flow stress and have suggested the strength theory presented here. Unlike previous strength theories for ductile metals the present theory takes into account the short range inhomogeneities that are present in all engineering metals and does not ignore the fact that strain therefore occurs on discrete planes associated with the inhomogeneities rather than being uniformly distributed throughout the metal. A size effect naturally arises from this picture. The size effect for ductile metals might be referred to as a surface effect as opposed to the volume-type size effect that arises from Weibull's theory for brittle materials.

When certain well known processes are carefully examined, considerable evidence for a ductile size effect is found. A negligible effect is observed for ductile tensile specimens in the usual range of sizes (> 0.1 in.), while a significant size effect is noted for torsion specimens even for diameters of 1 in. and over. These observations are in agreement with the theory and the difference in performance for tensile and torsion specimens with regard to diameter is associated with the stress gradient that is present in the case of the torsion specimen. Despite an equality of diameters, the size of the zones of plastic flow differ in the two tests. In the tensile test yield will occur in the entire bar from the center to the free surface whereas in the torsion test yield will occur in a relatively thin layer near the free surface.

The failure of Kick's law of similarity (which states that geometrically similar specimens of the same metal should exhibit the same flow stress) in the case of hardness testing by micro techniques has also been explained. Here the difficulty lies not with Kick's law but the failure to recognize that metals do not have the same properties in all thicknesses and hence are not the "same" for layers of all depths.

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SOME PROPERTIES OF HYPERBOLIC COORDINATE SYSTEMS

BY

W. H. BURROWS [1]

SUMMARY

Previous articles on the construction of nomographs with hyperbolic coordinates have dealt only briefly with the properties of the coordinate systems, attention being devoted primarily to practical applications. Extensive application of these methods, however, requires imagination and the freedom to select among, or depart from, the various types of coordinate systems suitable for the construction of nomographs. These requirements cannot be met without a clear mental picture of the properties of hyperbolic coordinate systems in general, and their relationships to cartesian coordinates. The purpose of the present article is to close the many gaps left by the treatment given in previous articles, and to provide a concise and systematic theoretical background for further application of these methods.

The coordinate system described in this article was devised as an aid in the construction of nomographs. In that field it becomes necessary at times to employ the methods of projective geometry to produce a satisfactory arrangement of scales and index lines. However, the methods in common use, based on the analytical geometry of cartesian coordinates, are often cumbersome and tedious in this field of application. It has been found preferable in many cases to define the scales and index lines in terms of a less specific coordinate system, such that the coordinate system could be modified to produce the required arrangement of scales and index lines, thereby avoiding the extensive arithmetical treatment associated with cartesian projective transformations.

In Fig. 1 are shown some of the infinite number of projective relationships existing among three points on a line. These relationships are produced in synthetic geometry by the method of alternate projection and section, as shown in Fig. 1. Analytically, this relationship may be expressed by a sequence of zero-valued determinants, each of which may be obtained from the preceding by multiplication by a non-vanishing "matrix of transformation" (**4**).[2] The synthetic method involves no coordinate system; the analytic method, the cartesian coordinate system. The coordinate system described in this article includes in its description a modifying factor such that a change in the value of that factor will cause a figure of three collinear points to go into certain of its projections.

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[2] The bold face numbers in parentheses refer to the references appended to this paper.

A METHOD FOR THREE POINTS ON A LINE

The positions of a point relative to two fixed points on the same line in all its projectivities may be described by the three points, 0, x, and 1 on the X-axis, where x may take on all values of $-\infty \leq x \leq +\infty$. The projectivity is a result of a modification in the value of the abscissa x. The abscissa may, however, be defined as p, the relationship between

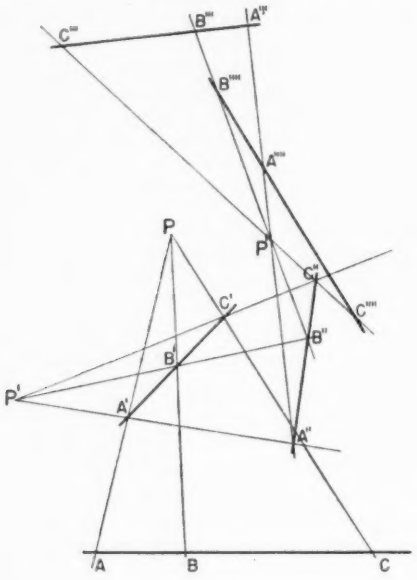

FIG. 1.

the two abscissas being $x = p/(p + r)$, where r is a constant which may take on any value. The projectivities of the three points, 0, p, and ∞ (corresponding to the above 0, x, and 1) may then be realized by varying the value of r (a constant of the coordinate system) rather than the

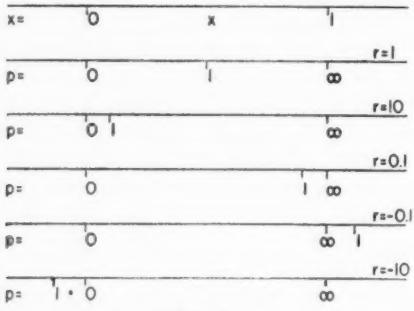

FIG. 2.

abscissa p (Fig. 2). The advantage of this in the field of nomography lies in the fact that the abscissa (x or p) is frequently a complicated function whose evaluation is tedious, whereas r is a simple number, often an integer.

HYPERBOLIC PLANE COORDINATES

Points on the Axes

The axes of hyperbolic plane coordinates consist of two straight lines intersecting at a finite point, the origin, at an angle θ such that θ is not equal to zero or any integral multiple of π. There is no advantage to be gained in the present discussion by considering special cases, such as $\theta = \pi/2$ (rectangular coordinates). These axes are designated X and Y and are superimposable upon the corresponding axes of a cartesian coordinate system whose axes form an angle equal to θ.

A point on the X-axis has the abscissa p_x, the relationship of this abscissa to its cartesian abscissa being

$$x = p_x/(p_x + r_x). \tag{1}$$

The ordinate of a point on the Y-axis is p_y, the relationship to the cartesian ordinate being

$$y = p_y/(p_y + r_y). \tag{2}$$

The values of r_x and r_y are independent. For all values of r_x and r_y, there are two fixed points on each axis: the *origin* ($p = 0$) and the point $p = \infty$ ($x = 1$ on the X-axis, $y = 1$ on the Y-axis) known as the *terminus*.

The relationship of Eqs. 1 and 2 to the cartesian hyperbola $y = x/(x + a)$ gives rise to the name "hyperbolic coordinates."

Points in the Plane

In cartesian coordinates, all points having a given abscissa lie on a line parallel to the Y-axis. All such lines converge at the point $y = \infty$. Ordinates are similarly related to a family of lines converging at the point $x = \infty$. These points may be regarded as the termini of the cartesian Y- and X-axes, respectively.

In the hyperbolic plane, all points having a given abscissa lie on a line passing through the terminus ($p'_y = \infty$) of the Y-axis, while points having a given ordinate lie on a line passing through the terminus of the X-axis (Fig. 3). In cartesian coordinates, points having an infinite ordinate or abscissa lie on the *ideal line* (the line passing through the termini of the cartesian X- and Y-axes), that is, at infinite distance from the origin. The association of infinite coordinate with infinite distance from the origin is not always a fortunate one. In hyperbolic coordinates, points having the finite coordinate $p_x = -r_x$ or $p_y = -r_y$ lie on the ideal line. Points having infinite coordinates, $p_x = \infty$ or $p_y = \infty$, lie on the line passing through the termini of the hyperbolic X- and Y-axes (a finite line).

All finite points may be located with respect to the hyperbolic X- and Y-axes, with the exception of points lying on the line passing through the termini of those axes, since in this case both p_x and p_y are infinite. It is necessary, therefore, to define points on that line with respect to its fixed points, which are the termini of the X- and Y-axes. In so doing, it is desirable to consider the segment of that line lying between the two termini as being of unit length (as with the X- and Y-axes), unit length not being necessarily the same for any two of the three lines. The point at which this line intersects the X-axis is taken to be its origin, its terminus being at the intersection with the Y-axis. A point on this line, known as the $\bar{Z}$-axis, is designated by the hyperbolic ordinate, $p_{\bar{z}}$, the relationship to its cartesian ordinate being

$$y = p_{\bar{z}}/(p_{\bar{z}} + r_{\bar{z}}). \tag{3}$$

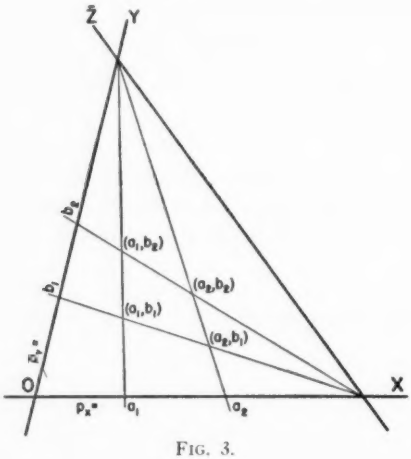

FIG. 3.

The equation of the $\bar{Z}$-axis, with respect to the corresponding cartesian coordinates (since it passes through the points (1, 0) and (0, 1)) is $x + y = 1$. Hence, the cartesian abscissa of a point on the $\bar{Z}$-axis is

$$x = 1 - y = r_{\bar{z}}/(p_{\bar{z}} + r_{\bar{z}}). \tag{4}$$

For the purpose of simplifying the relationship of points on the $\bar{Z}$-axis to other points in the plane, it is desirable to assign to $r_{\bar{z}}$ the arbitrary value,

$$r_{\bar{z}} = r_y/r_x. \tag{5}$$

Coordinates of Points in the Plane

The relationship between the hyperbolic and cartesian coordinates of a point in the plane is of value in deriving the hyperbolic equations

of geometric figures from the familiar corresponding equations in cartesian coordinates. These relationships may be derived from the equations of the coordinate lines, as shown in Fig. 4. The equation of the abscissa line, which passes through the points (0, 1), (x, y), and $(p_x/(p_x + r_x), 0)$ is $x = p_x(1 - y)/(p_x + r_x)$; while that of the ordinate line, which passes through the points (1, 0), (x, y), and $(0, p_y/(p_y + r_y))$ is $y = p_y(1 - x)/(p_y + r_y)$. Simultaneous solution of these equations gives the following values of x and y:

$$\left.\begin{aligned} x &= p_x r_y/(p_x r_y + p_y r_x + r_x r_y) \\ y &= p_y r_x/(p_x r_y + p_y r_x + r_x r_y) \end{aligned}\right\}. \tag{6}$$

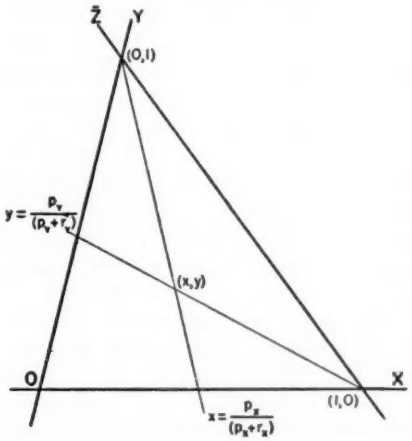

FIG. 4.

At times it is desirable to give the position of a point in the plane in terms of the $\bar{Z}$-axis and one of the other axes. In so doing, the $\bar{z}$-coordinate line is taken as the line through the origin of the X- and Y-axes, the point in question, and a point $p_{\bar{z}}$ on the $\bar{Z}$-axis. The equation of this line, passing through the points (0, 0), (x, y), and $(r_{\bar{z}}/(p_{\bar{z}} + r_{\bar{z}}), p_{\bar{z}}/(p_{\bar{z}} + r_{\bar{z}}))$, is $p_{\bar{z}} = yr_{\bar{z}}/x$. Substitution in this expression of the value of $r_{\bar{z}}$ (Eq. 5) and the values of x and y (Eq. 6) results in the relationship,

$$p_{\bar{z}} = p_y/p_x. \tag{7}$$

The reciprocal relations are given by the equations (derived from Eqs. 6 and 7):

$$\left.\begin{aligned} p_x/r_x &= x/(1 - x - y) \\ p_y/r_y &= y/(1 - x - y) \\ p_{\bar{z}}/r_{\bar{z}} &= y/x. \end{aligned}\right\}. \tag{8}$$

EQUATION OF THE STRAIGHT LINE

The condition that three points (x_1, y_1), (x_2, y_2), and (x_3, y_3) lie on a straight line is that the following determinant vanish; that is,

$$\begin{vmatrix} y_1 & x_1 & 1 \\ y_2 & x_2 & 1 \\ y_3 & x_3 & 1 \end{vmatrix} = 0. \tag{9}$$

If the hyperbolic equivalents of the cartesian coordinates be substituted in Eq. 9, the resulting determinant is

$$\begin{vmatrix} \frac{p_{y_1} r_x}{F_1} & \frac{p_{x_1} r_y}{F_1} & 1 \\ \frac{p_{y_2} r_x}{F_2} & \frac{p_{x_2} r_y}{F_2} & 1 \\ \frac{p_{y_3} r_x}{F_3} & \frac{p_{x_3} r_y}{F_3} & 1 \end{vmatrix} = 0,$$

in which $F_i = p_{x_i} r_y + p_{y_i} r_x + r_x r_y$ $(i = 1, 2, 3)$.

This determinant is simplified by subtracting both the first and second columns from the third column to form a new third column, after which certain obvious factors may be removed from the determinant, thus,

$$\frac{r_x^2 r_y^2}{F_1 F_2 F_3} \begin{vmatrix} p_{y_1} & p_{x_1} & 1 \\ p_{y_2} & p_{x_2} & 1 \\ p_{y_3} & p_{x_3} & 1 \end{vmatrix} = 0. \tag{10}$$

Except for a certain case to be discussed shortly, the factor preceding the determinant does not vanish; whence,

$$\begin{vmatrix} p_{y_1} & p_{x_1} & 1 \\ p_{y_2} & p_{x_2} & 1 \\ p_{y_3} & p_{x_3} & 1 \end{vmatrix} = 0 \tag{11}$$

is the condition that the three points (p_{x_1}, p_{y_1}), (p_{x_2}, p_{y_2}), and (p_{x_3}, p_{y_3}) lie on a straight line. This condition is loosely referred to in nomography as the equation of the straight line (1).

The determinant of Eq. 11 is independent of the factors r_x and r_y; consequently, it is possible to produce on any line in the plane all those projections of three points shown in Fig. 2 without changing the values of the hyperbolic coordinates of those points, the projection being accomplished by varying the values of r_x and r_y.

The only instance, except for the absurd case $r_x = 0$ or $r_y = 0$, in which the factor preceding the determinant of Eq. 10 vanishes is that in which p_{x_i} or p_{y_i} becomes infinite, that is, when the point lies on the Z-axis. In this case, convenient substitutions to be made in Eq. 9

for that point may be derived from Eqs. 3, 4, and 5:

$$x_i = r_{\bar{z}}/(p_{\bar{z}_i} + r_{\bar{z}}) = r_y/(p_{\bar{z}_i} r_x + r_y)$$
$$y_i = p_{\bar{z}_i}/(p_{\bar{z}_i} + r_{\bar{z}}) = p_{\bar{z}_i} r_x/(p_{\bar{z}_i} r_x + r_y).$$

Substitution of these expressions in Eq. 10 for the point lying on the $\bar{Z}$-axis and of the expressions in Eq. 6 for the other two points, followed by the simplification indicated above, leads to a determinant preceded by a factor which does not vanish; whence, the resulting determinant form of the equation of the straight line with one point on the $\bar{Z}$-axis becomes

$$\begin{vmatrix} p_{y_1} & p_{x_1} & 1 \\ p_{y_2} & p_{x_2} & 1 \\ p_{\bar{z}} & 1 & 0 \end{vmatrix} = 0. \tag{12}$$

The general equation of the straight line in hyperbolic coordinates is Eq. 11. The appearance of a cipher in a row of the determinant indicates a point on one of the axes, as follows: first column, X-axis; second column, Y-axis; third column, $\bar{Z}$-axis. In the last case, the 1 appears in the second column instead of the third, as in the other two cases.

THE HYPERBOLIC NUCLEUS

The triangle formed by the X-, Y-, and $\bar{Z}$-axes may be regarded as the "nucleus" of a network formed by three pencils of lines. The X-pencil converges at the terminus of the Y-axis (and $\bar{Z}$-axis), which lies at the apex of the nucleus directly opposite the X-axis. The lines of this pencil intersect the X-axis at the points $x_i = p_{x_i}/(p_{x_i} + r_x)$. The Y- and $\bar{Z}$-pencils bear a similar relationship to the Y- and $\bar{Z}$-axes, respectively. Thus, each pencil may be regarded as intersecting one side (or axis) of the nucleus in a series of hyperbolic segments, the other two sides (or axes) of the nucleus being members of that same pencil.

It may now be shown that each of the pencils of lines also intersects every line which may be drawn in the plane in a series of hyperbolic segments, $x'_i = l_{x'} p_{x_i}/(p_{x_i} + r_{x'})$, $l_{x'}$ being the length of the line segment bounded by the p_0 member and the p_∞ member of the intersecting pencil. The corresponding values of r are, for lines intersected by the X-pencil,

$$r_{x'} = (p'_y + r_y)/(p'_{\bar{z}} + r_{\bar{z}});$$

for lines intersected by the Y-pencil,

$$r_{y'} = (p'_x + r_x)/\left(\frac{1}{p'_{\bar{z}}} + \frac{1}{r_{\bar{z}}}\right); \tag{13}$$

for lines intersected by the $\bar{Z}$-pencil,

$$r_{\bar{z}'} = \left(\frac{1}{p'_x} + \frac{1}{r_x}\right)\Big/\left(\frac{1}{p'_y} + \frac{1}{r_y}\right),$$

where p'_x, p'_y, and $p'_{\bar{z}}$ are the points of intersection of the line with the X-, Y-, and $\bar{Z}$-axes, respectively, while r_x, r_y, and $r_{\bar{z}}$ are the respective hyperbolic constants of those axes.

Of course, every line in the plane, other than lines on the vertices of the nucleus, is intersected by all three pencils and is, consequently, subdivided by those pencils into hyperbolic segments whose constants have the values given in Eqs. 13. For any given line, the relationship of its three hyperbolic constants, from Eqs. 13, is

$$r_{\bar{z}'} = r_{y'}/r_{x'}. \tag{14}$$

Derivation of Eq. 13 for the X-Pencil

Let aa' (Fig. 5) be a line in the plane of the nucleus, intersecting

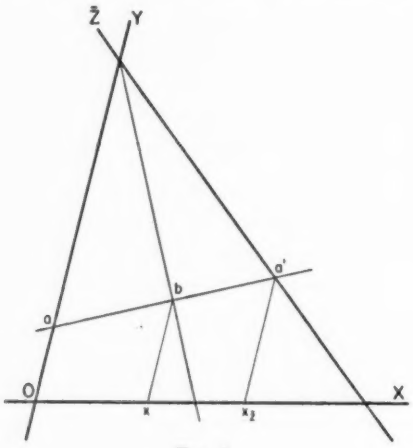

FIG. 5.

the Y-axis at p'_y and the $\bar{Z}$-axis at $p'_{\bar{z}}$. From Eq. 12, the equation of this line is

$$\begin{vmatrix} p'_y & 0 & 1 \\ p_y & p_x & 1 \\ p'_{\bar{z}} & 1 & 0 \end{vmatrix} = 0,$$

or $p_y = p_x p'_{\bar{z}} + p'_y$.

The ratio of the length of $\overline{ab}$ to that of $\overline{aa'}$ is equal to the ratio of x to $x_{\bar{z}}$ on the X-axis. If this ratio is designated x', then

$$x' = \overline{ab}/\overline{aa'} = x/x_{\bar{z}}.$$

But, by Eq. 6, $x = p_x r_y/(p_x r_y + p_y r_x + r_x r_y)$ and, by Eq. 4, $x_{\bar{z}} = r_{\bar{z}}/(p_{\bar{z}} + r_{\bar{z}})$. Substitution of these values, and of the value of p_y given above, leads to the expression

$$x' = p_x \Big/ \left[p_x + \frac{p'_y + r_y}{p'_{\bar{z}} + r_{\bar{z}}} \right].$$

For a given line in the plane, $(p'_y + r_y)/(p'_{\bar{z}} + r_{\bar{z}})$ is a constant. If this constant is designated $r_{x'}$, then

$$x' = p_x/(p_x + r_{x'}). \qquad \text{Q.E.D.}$$

The values of $r_{y'}$ and $r_{\bar{z}'}$ may be established in similar manner.

The relationship of points on the X-axis to points with equal hyperbolic abscissas on any line intersecting the X-pencil is a projective relationship. The X-pencil may be regarded as the projection; the intersecting line as the section. Projections of a figure of points on the X-axis may be realized by this method of projection and section. However, as has now been shown, this method of projection and section has the same effect as varying the value of r_x, since the distribution of points on the section is identical with that produced by substitution in Eq. 1 of the value of $r_{x'}$ given in Eq. 13.

PARALLEL LINES

Slope of a Line

The slope of a line in the hyperbolic plane is $m = (y'_{\bar{z}} - y')/x'_{\bar{z}}$, where $x'_{\bar{z}}$ and $y'_{\bar{z}}$ are the cartesian coordinates of its point of intersection with the $\bar{Z}$-axis and y' is its y-intercept. Substituting the values of these given in Eqs. 2 through 5 and Eq. 13 yields the relationship

$$m = 1 - r_x/r_{x'}, \tag{15}$$

where r_x and $r_{x'}$ are the hyperbolic constants with respect to the X-pencil of the X-axis and the line with slope m, respectively.

Parallel Lines

It is obvious from Eq. 15 that the necessary and sufficient condition that two lines, a and b, be parallel is that $r_{x'}(a) = r_{x'}(b)$. It may be shown in similar manner that in two such lines $r_{y'}(a) = r_{y'}(b)$ and that $r_{\bar{z}'}(a) = r_{\bar{z}'}(b)$. This principle is applied in rectifying nomographic scales (3).

SEMIHYPERBOLIC COORDINATES

In the field of nomography extensive use is made of a modified form of hyperbolic coordinates, properly called semihyperbolic, since only the X-axis is hyperbolic, the Y-axis being linear. This form of coordinates is arrived at as follows:

In the definition of hyperbolic coordinates, the length of the Y-axis was taken as unity, there being no loss of generality by so doing. In the modification now to be made, the length of the Y-axis, l_y, must be considered variable; whence, $y = l_y p_y/(p_y + r_y)$ gives the distance of a point p_y from the origin of the Y-axis. The values of l_y and r_y are now allowed to approach infinity simultaneously, while the ratio l_y/r_y

retains a constant value, m_y, that is, $l_y = r_y m_y$; whence,

$$y = \lim_{l_y, r_y \to \infty} \frac{l_y p_y}{r_y} \Big/ \left[\frac{p_y}{r_y} + 1 \right] = p_y m_y.$$

Here m_y is the constant commonly known as the *modulus* of the Y-axis, effectively the length of that axis representing an increase of 1 in the value of p_y. Of course, the length of the $\bar{Z}$-axis and the value of $r_{\bar{z}}$ approach infinity simultaneously with l_y and r_y, the $\bar{Z}$-axis becoming linear and parallel to the Y-axis. The value of $l_{\bar{z}}/r_{\bar{z}}$ as l_y becomes infinite has the value $l_y r_x / r_y = r_x m_y = m_{\bar{z}}$, the modulus of the $\bar{Z}$-axis.

Properties of semihyperbolic coordinates and their use in the construction of nomographs are described in a previous article (1) and will not be repeated here.

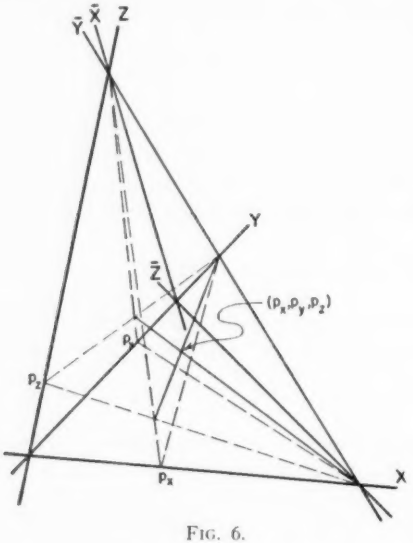

FIG. 6.

It is obvious that modification of the X-axis might be made in a manner similar to that given for the Y-axis. If both axes be modified in this manner, a coordinate system identical with cartesian coordinates is obtained. Hence, cartesian coordinates may be considered a special case of hyperbolic coordinates.

HYPERBOLIC SOLID COORDINATES

Hyperbolic solid coordinates consist of three axes, X, Y, and Z, corresponding to the X-, Y-, and Z-axes of cartesian solid coordinates. Points on these axes are defined by the expressions given for x and y in Eqs. 1 and 2, and by $z = p_z/(p_z + r_z)$. Values of r_x, r_y, and r_z are independent. Origin and termini are defined as in plane coordinates.

Each pair of axes determines a plane in which those axes are the principal axes of a plane hyperbolic system (Fig. 6). Positions of points lying in the planes of the axes are determined with respect to their principal axes in the manner given for plane coordinates. Points having infinite abscissa and ordinate lie on auxiliary axes: in the XY-plane, this is the $\bar{Z}$-axis; in the XZ-plane, the $\bar{Y}$-axis; and in the YZ-plane, the $\bar{X}$-axis (Fig. 6). There are, then, three principal and three auxiliary axes for locating points in the coordinate planes. It will be noted that the symbol ($^-$) added to a letter denotes an auxiliary axis which is *not concurrent* with the principal axis having the corresponding letter. Thus, the $\bar{Z}$-axis is not concurrent with the Z-axis, although all the remaining axes (principal and auxiliary) are. This convention is adopted because of the symmetry it imparts to certain relationships of the solid hyperbolic nucleus.

The hyperbolic constants of the auxiliary axes are related to those of the principal axes by the arbitrary values, $r_{\bar{z}} = r_y/r_x$, $r_{\bar{y}} = r_x/r_z$, and $r_{\bar{x}} = r_z/r_y$.

Positions of points in space are determined by three planes, each lying on one of the auxiliary axes and passing through a point on the corresponding principal axis (Fig. 6). Cartesian coordinates of a point in space (p_x, p_y, p_z) are derived through a consideration of the planes determining its position. The equations of these planes are

$$x + p_x(y + z - 1)/(p_x + r_x) = 0,$$
$$y + p_y(x + z - 1)/(p_y + r_y) = 0,$$
$$z + p_z(x + y - 1)/(p_z + r_z) = 0.$$

Simultaneous solution of these equations gives the values

$$x = p_x r_y r_z / F,$$
$$y = p_y r_x r_z / F,$$
$$z = p_z r_x r_y / F,$$

where $F = p_x r_y r_z + p_y r_x r_z + p_z r_x r_y + r_x r_y r_z$.

Equation of the Plane

The condition that four points (x_1, y_1, z_1), (x_2, y_2, z_2), (x_3, y_3, z_3), and (x_4, y_4, z_4) lie on a plane is that the following determinant vanish; that is,

$$\begin{vmatrix} z_1 & y_1 & x_1 & 1 \\ z_2 & y_2 & x_2 & 1 \\ z_3 & y_3 & x_3 & 1 \\ z_4 & y_4 & x_4 & 1 \end{vmatrix} = 0. \qquad (17)$$

The hyperbolic values of these cartesian coordinates may be substituted in this determinant. Then subtraction of columns 1, 2, and 3 from column 4, followed by removal of certain factors, leaves the

following relationship:

$$\frac{r_x^3 r_y^3 r_z^3}{F_1 F_2 F_3 F_4} \begin{vmatrix} p_{z_1} & p_{y_1} & p_{x_1} & 1 \\ p_{z_2} & p_{y_2} & p_{x_2} & 1 \\ p_{z_3} & p_{y_3} & p_{x_3} & 1 \\ p_{z_4} & p_{y_4} & p_{x_4} & 1 \end{vmatrix} = 0.$$

Except for points lying on the auxiliary axes or on the plane through those axes, the F's are finite numbers; hence, the factor preceding the determinant does not vanish. Consequently, for points with finite coordinates,

$$\begin{vmatrix} p_{z_1} & p_{y_1} & p_{x_1} & 1 \\ p_{z_2} & p_{y_2} & p_{x_2} & 1 \\ p_{z_3} & p_{y_3} & p_{x_3} & 1 \\ p_{z_4} & p_{y_4} & p_{x_4} & 1 \end{vmatrix} = 0 \qquad (18)$$

expresses the condition that four points $(p_{x_i}, p_{y_i}, p_{z_i})$ ($i = 1, 2, 3$, and 4) lie on a plane.

Modifications of Eq. 18 result when a point lies on one of the coordinate planes or on the plane through the three termini (the $\bar{X}\bar{Y}\bar{Z}$-plane). These modifications arise through substitutions similar to those encountered in the equation of the straight line in plane hyperbolic coordinates, followed by factoring by the steps given above. These modifications result in characteristic rows in the determinant, as follows:

$\begin{vmatrix} 0 & p_{y_i} & p_{x_i} & 1 \end{vmatrix}$ for a point in the $XY\bar{Z}$-plane,
$\begin{vmatrix} p_{z_i} & 0 & p_{x_i} & 1 \end{vmatrix}$ for a point in the $X\bar{Y}Z$-plane,
$\begin{vmatrix} p_{z_i} & p_{y_i} & 0 & 1 \end{vmatrix}$ for a point in the $\bar{X}YZ$-plane, and
$\begin{vmatrix} p_{\bar{z}_i} & p_{\bar{y}_i} & 1 & 0 \end{vmatrix}$ for a point in the $\bar{X}\bar{Y}\bar{Z}$-plane.

For the values of x, y, and z of a point in the $\bar{X}\bar{Y}\bar{Z}$-plane, one may consider the equation of that plane, which is $x + y + z = 1$. But in that plane, $y = p_{\bar{y}} r_{\bar{z}} / (p_{\bar{y}} r_{\bar{z}} + p_{\bar{z}} r_{\bar{y}} + r_{\bar{y}} r_{\bar{z}})$ and $z = p_{\bar{z}} r_{\bar{y}} / (p_{\bar{y}} r_{\bar{z}} + p_{\bar{z}} r_{\bar{y}} + r_{\bar{y}} r_{\bar{z}})$; whence, $x = r_{\bar{y}} r_{\bar{z}} / (p_{\bar{y}} r_{\bar{z}} + p_{\bar{z}} r_{\bar{y}} + r_{\bar{y}} r_{\bar{z}})$. But $r_{\bar{z}} = r_y / r_z$ and $r_{\bar{y}} = r_z / r_x$; hence, $x = r_y r_z / F'$, $y = p_{\bar{z}} r_x r_z / F'$, and $z = p_{\bar{y}} r_x r_y / F'$, where $F' = p_{\bar{y}} r_x r_y + p_{\bar{z}} r_x r_z + r_y r_z$. Substitution of these values in a row of Eq. 17, followed by the steps employed above for simplification, leads to the characteristic row for a point in the $\bar{X}\bar{Y}\bar{Z}$-plane as given above.

Characteristic rows for points lying on the axes are arrived at in similar manner and are

$\begin{vmatrix} 0 & 0 & p_{x_i} & 1 \end{vmatrix}$ for a point on the X-axis,
$\begin{vmatrix} 0 & p_{y_i} & 0 & 1 \end{vmatrix}$ for a point on the Y-axis,
$\begin{vmatrix} p_{z_i} & 0 & 0 & 1 \end{vmatrix}$ for a point on the Z-axis,
$\begin{vmatrix} p_{x_i} & 1 & 0 & 0 \end{vmatrix}$ for a point on the $\bar{X}$-axis,
$\begin{vmatrix} p_{\bar{y}_i} & 0 & 1 & 0 \end{vmatrix}$ for a point on the $\bar{Y}$-axis, and
$\begin{vmatrix} 0 & p_{\bar{z}_i} & 1 & 0 \end{vmatrix}$ for a point on the $\bar{Z}$-axis.

THE HYPERBOLIC SOLID NUCLEUS

The tetrahedron formed by the four planes bounded by the X-, Y-, Z-, $\bar{X}$-, $\bar{Y}$-, and $\bar{Z}$-axes may be regarded as the "nucleus" of a matrix formed by six bundles of planes. The X-bundle converges on the axis opposite the X-axis in the nucleus, that is, on the $\bar{X}$-axis; the Y-bundle on the $\bar{Y}$-axis, etc.

It may now be shown that these bundles of planes intersect every plane in the hyperbolic space in such a manner as to form a plane hyperbolic nucleus whose principal axes are the lines of intersection of that plane with the planes of the solid hyperbolic nucleus. Consider first a plane intersecting the $\bar{X}YZ$-, $X\bar{Y}Z$-, and $\bar{X}\bar{Y}\bar{Z}$-planes. Its intersection with the $X\bar{Y}Z$-plane is subdivided by the same bundle of

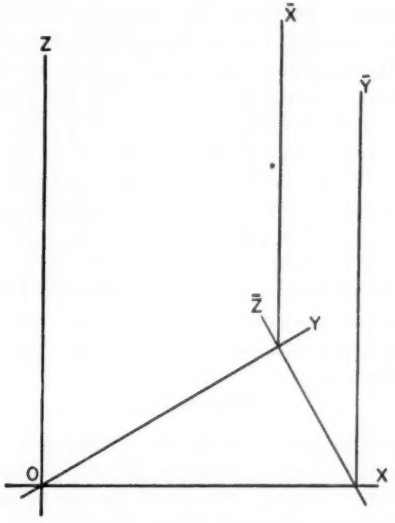

FIG. 7.

planes which subdivides the X-axis; hence,[3] it forms an X'-axis whose hyperbolic constant is $r_{x'} = (p'_x + r_x)/(p'_{\bar{y}} + r_{\bar{y}})$. Its intersection with the $\bar{X}YZ$-plane is subdivided by the same bundle of planes which subdivides the Y-axis; hence, it forms a Y'-axis whose hyperbolic constant is $r_{y'} = (p'_z + r_z)/(p'_{\bar{z}} + r_{\bar{z}})$. Its intersection with the $\bar{X}\bar{Y}\bar{Z}$-plane is subdivided by the same bundle of planes which subdivides the $\bar{Z}$-axis, hence it forms a $\bar{Z}'$-axis whose hyperbolic constant is $r_{\bar{z}'} = (p'_{\bar{y}} + r_{\bar{y}})/(p'_{\bar{z}} + r_{\bar{z}})$. From the above values of $r_{x'}$, $r_{y'}$ and $r_{\bar{z}'}$, it is obvious that $r_{\bar{z}'} = r_{y'}/r_{x'}$. Thus, the hyperbolic constants of the

[3] Cf. section on Hyperbolic Plane Coordinates, p. 129.

axes of the $X'Y'\bar{Z}'$-plane bear the same relationship to each other as do those of the $XY\bar{Z}$-plane.

In similar manner it may be shown that a plane intersecting any three of the coordinate planes of the solid hyperbolic nucleus forms a plane nucleus whose hyperbolic constants are related in the same manner as are those of the fourth coordinate plane of the nucleus. Since these values may be derived by inspection, using the relationships given by Eqs. 13, it is unnecessary to list them here.

SEMIHYPERBOLIC SOLID COORDINATES

Hyperbolic solid coordinates may be modified after the same manner as hyperbolic plane coordinates by the length and hyperbolic constant of any one of its principal axes being allowed to approach infinity simultaneously, provided the ratio $l_u/r_u (u = x, y, z)$ remains constant. For the construction of three-dimensional nomographs (3), the form of coordinates most easily adaptable is that in which the length and hyperbolic constant of the Z-axis have been permitted to approach infinity. The resulting system (Fig. 7) consists of a triangular hyperbolic plane ($XY\bar{Z}$-plane) with vertical axes arising from its three vertices. The vertical axes are parallel and linear, their moduli (derived in the same manner as with plane semihyperbolic coordinates) being related as follows: $m_{\bar{x}} = r_y m_z$ and $m_{\bar{y}} = r_x m_z$.

Obviously, any one, two, or three of the principal axes of solid coordinates may be allowed to approach infinite length (and infinite value of its hyperbolic constant). In the event that all three principal axes do so, the resulting coordinate system is identical with the cartesian solid coordinate system.

CONCLUSIONS

It has been shown that varying the value of r_x makes it possible to produce within the X-axis (that is, in one dimension) all possible projections of a figure having two fixed points collinear with a third point, thereby obviating for such cases the method of projection and section employing two dimensions. That similar projections of a three-point line figure may be produced on any line in the plane by varying r_x and/or r_y was shown in the discussion of the plane hyperbolic nucleus.

Likewise, every projection of the $XY\bar{Z}$-plane is an $X'Y'\bar{Z}'$-plane which differs from the $XY\bar{Z}$-plane only in the values of r_x and r_y. Hence, it follows that it is possible to produce within the $XY\bar{Z}$-plane (that is, in two dimensions) projections of a plane figure, merely by the values of r_x and r_y being varied, thereby obviating the method of projection and section employing three dimensions.

Similarly, varying the values of r_x, r_y, and r_z is a means of realizing projections of a solid figure. It is also possible to do this analytically,

although, for many purposes, the analytical approach is much more difficult. In the field of nomography, for example, the construction of three-dimensional nomographs has been largely avoided because analytical methods of projection, when applied to any but the simplest defining equations, is not only very laborious, but also fails to provide the ease of visualization inherent in the hyperbolic coordinate system.

This ease of visualizing the projections of a figure (plane or solid) is enhanced by the fact that the mind readily considers variation in the value of the hyperbolic constant as a continuous process, with one-to-one correspondence between a figure and its projection. An analytical projection, being a discrete step, may be less easily visualized. In practical applications, this visualization is frequently valuable in avoiding unnecessary trials before finding the optimum projection for the purpose at hand.

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Entrained Air Indicator.—A improved entrained air indicator, designed for faster and more accurate determinations of entrained air content in freshly mixed concrete, has been developed by the Central Scientific Co., Chicago.

Made of cast magnesium alloy, the new entrained air indicator is more durable than the former steel models and its lighter weight makes it more convenient for cement contractors to carry in the field.

Air-entrained concrete is one of the most recent developments of concrete research and is destined to save the taxpayers a great deal of money in highway maintenance costs. The mixture contains billions of microscopic air cells which provide expansion chambers for water when it freezes inside the concrete, thereby reducing internal pressures which cause cracking, chipping and peeling.

The amount of entrained air required is usually between 3 and 6 per cent of the volume of the concrete, but may be varied under special conditions. Determining and controlling the percentage of entrained air is done by the Cenco air indicator which tests concrete samples by the pressure method. Air-entrained concrete is produced by introducing small amounts of resinous or fatty materials such as beef tallow or agents of the soap family.

A recent survey of fourteen experimental highway sections has proved that pavements made with air-entrained concrete withstand severe winter exposure, including frequent applications of ice-removing chemicals. Currently, thirty of the forty-eight states require its use in all pavements and eleven additional states permit its use under certain conditions. In addition to highway projects, air-entrained concrete has stood up on heavily traveled streets in Chicago, Milwaukee, Minneapolis, Detroit and other large cities.

Designer Foils Safe Snoopers.—If you need protection against snoopers, don't call the police: call in an industrial designer.

Snoopers are a problem to people who keep safes in their homes or offices. While the safe owner bends down to work the dial, it's easy for somebody to peek over his shoulder and steal the combination. Precious papers and valuables are at his mercy.

When the Mosler Safe Company, builder of the Ft. Knox vaults that protect the nation's gold, decided to create a new, completely modern safe, it sought a way to lick the combination-stealing problem. To assist, it called in world-famous industrial designer Raymond Loewy, who has helped create products varying from trash cans to locomotives.

Loewy's ingenuity turned out to be bad news for crooks.

His first step was to raise the position of the dial, so that need to stoop is eliminated and the body automatically screens the dial. Next, he shifted the numbers from the front to the edge of the dial and then added a stainless steel shield making it impossible to get a side view of the numbers. Now the combination numbers are visible only from the top and only to the person working the combination.

Mosler, with its 104 years of experience in the industry, predicts that this new design, called the "Counter-Spy Dial," will prevent the theft of hundreds of combinations, a form of robbery no policeman can thwart.

A UNIVERSAL UNIT FOR THE ELECTRICAL DIFFERENTIAL ANALYZER

BY

RAJKO TOMOVICH[1]

SUMMARY

This article describes an electromechanical unit which performs various mathematical operations occurring in the solution of differential equations by analog methods.

The mathematical operations in question are essentially those that cannot be solved by use of the conventional d-c. amplifier technique, for example, multiplication, generation of arbitrary functions of independent and dependent variables, etc.

It may be seen that a combination of the proposed units and d-c. amplifiers only, meets all requirements for a complete, general-purpose differential analyzer.

I. INTRODUCTION

Electrical differential analyzers have an important place among modern computing machines. The field of their application seems to be well established, but there are significant variations in the design of different machines.

It was our intention, in studying the problems relevant to electrical differential analyzers,[2] to develop a unit which could cover a wide range of problems with a minimum of basic elements and still keep the precision of the existing devices (1).[3]

To meet these requirements we developed, essentially, two basic elements. Conventional d-c. amplifiers with respective feed-backs perform such operations as addition, subtraction, integration, sign changing and, therefore, serve as a basis for the solution of the linear differential equations with constant coefficients.

In order to solve the more general cases, especially the non-linear problems, means for the generation of arbitrary functions of independent and dependent variables must be available as well as for multiplication, division, squaring, etc.

It will be shown that the universal unit described in this article—hereafter called U.U.—can take care of all the above-mentioned operations in the differential analyzer which cannot be solved by the use of d-c. amplifiers with appropriate feed-back.

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[2] The project as a whole was carried with the cooperation of Dr. Dusan Mitrovich, head of the Laboratory for Applied Mathematics, in Belgrade.

[3] The boldface numbers in parentheses refer to the references appended to this paper.

II. CONSTRUCTION

A. The Mechanical Part

This part consists fundamentally of a combination of rotating switches (Fig. 1). In Fig. 1, A_1, A_1, A_2, A_3 represent the disks with regularly spaced conducting and non-conducting segments; B_1, B_2, B_3, B_4 are designations for the necessary brushes; and R_1, R_2, and R_3 designate a whole group of corresponding disks and brushes which perform a special function in the U.U. The electrical interconnections between the various groups are shown in Fig. 2 (Part III), where the functioning of the U.U. is explained.

The four disks A_1, A_1, A_2, and A_3 are identical in construction and each of them has 60 segments whose conducting and non-conducting parts are in the ratio of 1:4. Actually, only fifty segments are used, the rest being free or used in operations necessary to make the solutions periodic. All brushes, except B'_3, are of the same width which is equal to that of the conducting part of a segment. The rotating switch R_1,

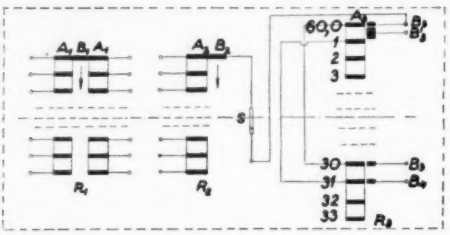

FIG. 1. Switching operations needed in the Universal Unit.

as seen from Fig. 1, has two poles. The moving brush B_1 simply short-circuits the opposite poles.

Group R_2 is a one-pole switch. The moving brush B_2, connected to a slip ring S, establishes contacts successively with all the segments. Group R_3 has stationary brushes and a moving disk. All diametrically opposite segments of the disk are short-circuited. The brush pair $B_3 - B_3$ lies also on a diameter, while brush B_4 faces the adjacent segment. The width of brush B'_3 is such as to cover the space between two contacts minus the gap which assures electrical isolation from B_3.

All rotating parts of the U.U. are mounted on the same shaft in such a way that switching is synchronous in different groups. The mechanical part as a whole can be coupled either to a d-c. motor or to a positioning servomechanism.

B. The Electrical Part

The U.U. was so designed that it can take full advantage of the possibilities offered by computing circuits already used in the differential analyzer for other purposes.

Originally, there was planned a special d-c. amplifier with gain one and a differential input, but this idea was abandoned since the universal direct-coupled differential amplifier of Goldberg (2) meets all the necessary requirements. In this way, the d-c. amplifiers used in the differential analyzer can serve in conjunction with the U.U. without any additional electronic components.

A third component of the U.U. consists of a set (in our case, fifty) of linear potentiometers to represent various functional relations.

III. APPLICATION

A. Generation of Functions of an Independent Variable

In order to generate a voltage of the general form $V = f(t)$, we can use either a continuous set of values of the function or a discrete one. Both methods have been used in electrical calculating machines (1, 3, 4, 5); however, from a practical point of view and, especially, with regard to its important possibilities in various other mathematical applications, the discrete form of the input data offers considerable advantages over the continuous case. Obviously, the discrete form of the input data may require that a smoothing process be included as a

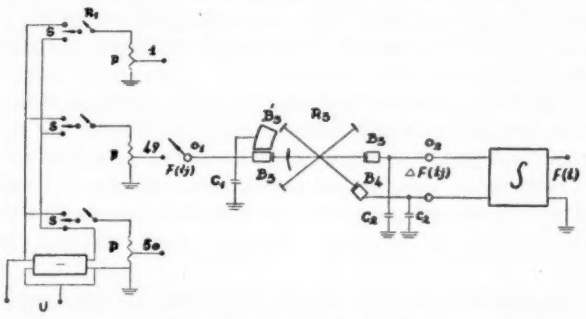

FIG 2. Basic diagram of the functioning of the Universal Unit.

part of the unit; but, in practice, the majority of the additional components needed already form part of the differential analyzer.

The smoothing process employed in the U.U. is based on the mathematical theory of interpolation so that a high degree of accuracy can be achieved and, on the other hand, the errors due to approximation by polynomials are known in advance. The general case of a practical realization of this method is fully described in an article by A. Porter and F. W. Stoneman (6). In our case we used linear interpolation between two consecutive voltage steps, taking into account the degree of accuracy of the whole analyzer. Means are also provided to set up positive and negative function values.

The whole process of generation of arbitrary functions can be understood from Fig. 2.

A constant voltage appears at the input. If needed, a sign changer available in the analyzer may be coupled to the input so that the potentiometers P can represent either positive or negative values, with the aid of the switches S.

There are fifty 100 k potentiometers, mounted on a panel, whose values can be set according to the given succession of the function ordinates. It is more convenient to set the potentiometer values with the aid of a special precision decade-potentiometer and the balancing method so that the input data are used directly in digital form. A precision of better than 0.1 per cent can be easily achieved in this way.

Rotating switches R_1 and R_2 serve to connect only one potentiometer at a time making the input impedance of the U.U. equal to that of a single potentiometer. Care must be taken when adjusting R_1 and R_2 to avoid possible discharging of condensers C through the potentiometers. However, the switch R_1 is not indispensable and a lighter mechanical design of the U.U. can be achieved if the input impedance is reduced. This fact is useful when working with the servomotor.

When we couple the U.U. to a constant-speed driving motor, a step function will appear at O in accordance with the potentiometer settings. We shall denote this function by $f(t_j)$, the independent variable being time, because of the constant speed of the motor. The proper speed of the d-c. motor is ultimately selected according to the types of the problems.

There is still the interpolation process to be performed in the U.U. For linear interpolation applied here, we need first-order differences. The whole process of obtaining first order differences had to be made automatic, because in the further applications of the U.U. important cases arise where the functions to be treated appear only when the differential analyzer is running. Besides, they are not known in advance.

As all rotating switches R_1, R_2, R_3 function synchronously, voltages $f(t_j)$ appear at the same time at O_1 and O_2. In the next interval, $f(t_j)$ is transferred to B_4, while B_3 has the potential corresponding to $f(t_{j+1})$. The role of the condensers is seen from Fig. 2. By this arrangement, only the voltage differences $\Delta f = f(t_{j+1}) - f(t_j)$ act on the integrator.

The universal d-c. integrator, which is the other basic element of the analyzer, performs the interpolation. At each moment t_j the voltage difference Δf is integrated according to

$$\frac{1}{RC}\int_0^{\Delta t} \Delta f dt = \frac{\Delta t}{RC}\Delta f + K = \frac{\Delta t}{RC}[f(t_{j+1}) - f(t_j)] + f(t_j)$$

$$= f(t_{j+1}), \text{ if } \frac{\Delta t}{RC} = 1.$$

One can avoid any shifting of the function along the t-axis, if the first value $f(t_0)$ is set as an initial condition on the integrator and

$f(t_1)$ is used as the starting ordinate on the potentiometers. Thus the arrangement in Fig. 2 makes it possible to obtain a linear approximation between two given function values. There is no restriction as to the sign of the function to be generated and, in addition, the sign needed in the equation is also available. The number of points depends, obviously, on the desired accuracy, but, in this case, it can be determined by mathematical means.

We can now summarize the merits of the above method:

1. A final precision of the order of 1 per cent, or better, can be achieved when generating various functions.
2. The change from one function to another is done by resetting the potentiometers.
3. Tabulated data are directly handled.
4. There is no need for precise potentiometers.
5. Rotating potentiometers are not necessary.
6. The U.U. may have a high input impedance.

B. Multiplication

If one of the two functions $f(t) \cdot \varphi(t)$ is known in advance, the U.U. can easily perform this operation. The diagram stays the same as in Fig. 2, except that at the input $\varphi(t)$ appears, while $f(t)$ is set on the potentiometers as before. The rotating switches R_1 and R_2 perform now a scanning process by gating only those values of $\varphi(t)$ which correspond to $f(t_j)$. At O_1 appear the products $\varphi(t_j) \cdot f(t_j)$ and, then, the same interpolation process takes place, as before.

An obvious practical difficulty arises here because the on-time of the switches is not instantaneous. However, the time the gate is open is only $\frac{1}{125}$ of the whole range of t, when ten segments are left free. On the other hand, the fixed values $f(t_j)$ are taken at the middle of the on-time of the rotating switches.

The importance of obtaining the first-order differences automatically can be clearly understood now. The interpolation process does not depend any longer on whether the first derivative of the function is known in advance, so that the field of application of the unit is enlarged. Another result is that the use of a servomotor for multiplication is avoided, with the restriction mentioned above. From a practical point of view it is important to note that the U.U. performs the multiplication in all four quadrants which is not always possible with other analog methods.

C. Generation of Functions of a Dependent Variable

In the application of the differential analyzer, important instances arise where a function of a dependent variable must be generated.

Indeed, these are the most valuable applications of the analyzer. We saw before that it is possible, starting with a set of given ordinates, to obtain a continuous function $f(t)$ at the output. The more general case of a function of a dependent variable obviously involves that t itself must be modulated according to another functional relation $\psi(t)$. In this case the output of the U.U. would be $f[\psi(t)]$ with $f(t)$ set on the potentiometers. The interpolation process is also included here.

For practical realization, the U.U. must now be coupled to a positioning servomotor and not to a constant speed drive. A conventional positioning instrument servosystem was used which establishes a linear correspondence between the applied voltage and angle (Fig. 3).

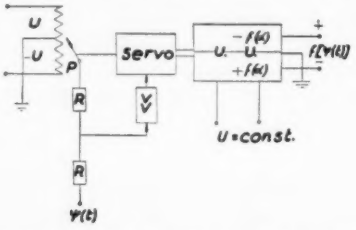

FIG 3. To generate functions of a dependent variable, the Universal Unit is coupled to a servosystem.

The voltages $+U$ and $-U$ provide the correct sign of $\psi(t)$. Their magnitude is easily adjusted to correspond to any $\psi(t)$. It must be taken into consideration that only half of the potentiometers are used for $f(t)$ in the general case, the other half being set with respect to $f[-\psi(t)]$. For instance, if $f[-\psi(t)]$ is odd, the other half is set with the $-$ minus sign $f[-\psi(t)] = -f[\psi(t)]$. In the opposite case, both halves keep the sign of $f(t)$. The scale factor depends on the voltage gradients $\frac{\Delta U}{\Delta \alpha_3}$ both on the U.U. and the linear potentiometer of the servosystem.

It is interesting to note that it makes no difference whether, instead of $U = \text{const.}$, there is a voltage $\varphi(t)$ at the input of the U.U. The same arrangement now performs the operation $\varphi(t) \cdot f[\psi(t)]$.

D. General Case of Multiplication and Division

If both functions to be multiplied are not known in advance, the multiplication can be performed in the usual way by applying the other voltage to a second potentiometer P (Fig. 3) according to the conventional servo-method. The same multiplication can be performed, however, without this additional potentiometer, if the U.U. is set to represent a linear relation and there is a variable voltage $\varphi(t)$ at the input, instead of $U = \text{const.}$

One very interesting application of the U.U. is to perform the division of two functions avoiding the usual feed-back technique.

It was shown previously that with a variable input and a servodrive the U.U. can perform the operation $\varphi(t)f[\psi(t)]$. The preceding case of multiplication is derived from the above formula, if f is set on the potentiometers according to the relation $f(t) = k \cdot t$.

To divide two functions, the same set-up is used, but, obviously, f now represents a reciprocal relation which is set on the U.U. The result is $\frac{\varphi(t)}{\psi(t)}$, where $\varphi(t)$ is applied to the input of the U.U. and $\psi(t)$ is used to position the servosystem.

In our opinion this method of division is a very good example of the broad facilities offered by the U.U. in computing processes.

E. Squaring and Taking Square Root

Following the same line of reasoning as in the previous section, the U.U. can be used to perform such operations as raising to a power of any kind, avoiding the iterative procedure. This means that only one unit is needed in each case.

When $f(t)$ is known in advance, we simply set on the potentiometers $f(t)^2$ or $\sqrt{f(t)}$, for instance.

If $\psi(t)$ comes out as a result in the course of the solution, we consider the square or any other power as a function of the dependent variable $f[\psi(t)] = \psi(t)^2$ and use the technique under Section III–*C*. The potentiometers are set to represent a squared function and $\psi(t)$ is the input of the servomechanism.

IV. CONCLUSION

In the preceding paragraphs several applications of the U.U. in the differential analyzer were described. Basically, this device can be treated as an adjustable non-linear potentiometer whose resolving power has been increased by using linear or higher order approximation between two steps. The accuracy in different applications ranges between 1 and 2 per cent as compared with the analytical solutions. Some experimental units will be designed with higher order approximations to decide on their usefulness and precision.

This device shows also some interesting features when used for other computing purposes. It is seen that multiplication of two functions can be done without a servosystem on the condition that one of them is known in advance. Thus, the U.U. offers a very practical means of computing, for instance, the Stieltjes integrals.

One possible application seems to deserve full attention. Professor Wallman (7) has recently proposed a computer to solve integral equa-

tions for example, to obtain the integral-transforms, of the type

$$F(x) = \int_a^b K(x,t) \cdot f(t)dt.$$

The main problem encountered was how to present the kernel $K(x,t)$ in the form of a voltage. He proposed to store it on a film and then read it photoelectrically.

We propose a solution which we feel is more practical, in which the U.U. only is used (Fig. 4). To illustrate more fully, a special case with $K(x,t) = e^{-x^2 t}$ is taken. This technique, however, is not so general as that of Prof. Wallman, since it is based on the use of two one-variable-function-generators.[4]

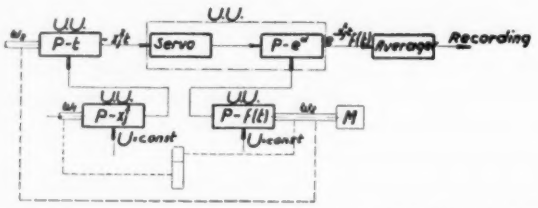

FIG 4. Obtaining the integral-transforms with the aid of the Universal Units. *P*, the set of the potentiometers of the Unit and the functional relation they represent.

The problem of two independent variables x and t has been solved, so that the speeds of the units representing x and t, ω_1 and ω_2, bear definite ratio. The t-unit makes a full rotation while the x-unit moves only one sector. In this way, there is no need for taking a "photograph" of the kernel and the U.U. serves as an easily adjustable storage device.

The proposed solution seems to be even more valuable when looking for the solution of an integral equation. The setting of the potentiometers of the U.U. represents a very direct way to shape the function $f(t)$ to satisfy the integral equation.

Further work is being carried on and will be published in another article. In trying to overcome the frequency limitations involved when the servosystems are used, we are now developing a U.U. where the servosystem is replaced by all electronic components. This means that it will be possible to use the U.U. in fast computing machines on an equal basis with other electronic elements in regards to frequency response (8).

The aim of this article was to propose the development of a cheap and flexible unit for use in computers or, independently, as a small auxiliary device.

[4] This restriction was pointed out in a very helpful letter from Professor Wallman.

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U. S. Isotope Distribution.—More than 600 universities, hospitals and research laboratories in 46 states are using isotopes produced by the U. S. Atomic Energy Commission for medical, biological, industrial, agricultural and scientific research and medical diagnosis and treatment, the Commission stated in a report recently.

The report, "Isotopes—A Five Year Summary of U. S. Distribution," is available to the public from the Superintendent of Documents, U. S. Government Printing Office, Washington 25, D. C., for $1.00 per copy. A summary of isotope applications considered to be of significance to industry has been compiled from the Five Year Summary and printed separately as document TID-5078 available at the Office of Technical Services, Department of Commerce, Washington 25, D. C., for 30 cents per copy.

The full report on isotope distribution for five years shows more than 18,900 shipments of radioactive isotopes and 1500 stable isotopes have been made to users in the United States and 1100 radioactive isotope shipments to users outside the United States.

A brief summary of the growth of the isotopes program and descriptions of their uses are included in the report with a list of the users and the titles of 1400 technical reports and papers published on isotope work in the past two years.

Gravity Mining of Nickel Ores.—Nature's old standby, the force of gravity, has been put to work deep beneath the earth's surface in a vast mining program that is helping maintain the free world's supply of nickel. It has given mining science the key to recovery of millions of tons of nickel-copper ore once regarded as worthless.

Engineers of The International Nickel Company of Canada, Limited, at its mines in the Sudbury District in Copper Cliff, Canada, have recently adapted a mining technique by which gigantic masses of ore, far underground, are induced to cave and disintegrate of their own weight, according to R. L. Beattie, Vice President and General Manager of the company's Canadian operations. Inco's engineers took their cue from observation of the natural tendency of the lower grade ore to subside and break up after higher grade ore beneath it was mined out.

Called "induced caving," this low-cost bulk mining method, plus metallurgical practices, makes it practicable for Inco to recover and treat ore lower in grade than it had ever worked in underground mining. Thus the supply of economically available ore has been broadened, aiding Inco in maintaining its current nickel production at a post-war high.

In caving, a "slice" which may contain as much as 1,500,000 tons of ore is undercut. As ore from the undercut slice is withdrawn, the slice to be mined breaks away and starts to disintegrate as it moves downward, the weight of the upper part of the mass acting to crush the ore at the bottom.

Another bulk mining technique by which Inco is boosting its underground production is the "blasthole" method. Blasthole mining differs from caving only insofar as explosives are used to break the slices of harder, tougher ore from the solid material. The force of gravity then takes over, as in caving.

In addition to these recent innovations the company continues to use a number of other mining methods by which the higher grade ores are extracted with relatively little dilution as in the past.

A CIRCUIT FOR THE LIMITATION OF DISCHARGE IN G-M COUNTERS *

BY

W. C. PORTER [1] AND W. E. RAMSEY [1]

ABSTRACT

A simple two tube feedback arrangement to limit the discharge in a counter to a small segment of its length subsequently restoring all but a small portion of the tube to full sensitivity in about a microsecond, has been achieved. The procedure results in a marked reduction in dead-time, and a correspondingly large increase in life. For example, a 20-cm. counter may be operated at a rate of 20,000 counts per second with a loss no greater than that normally encountered at 1000 counts per second. Counting rate data are given along with studies of the discharge distribution with and without the cut-off procedure. Alteration in the dead-time picture is illustrated by oscillograms.

INTRODUCTION

As conventionally used, the discharge in a G-M counter spreads, from one or more points, over the entire length of the wire. Subsequently, the tube remains unresponsive to radiation until such time as the positive ion sheath, in its motion toward the cathode, permits a restoration of the starting field. This "dead-time," which frequently is as long as one hundred microseconds, very seriously limits all applications wherein a counter must be used at high rates. The dead-time is particularly serious in coincidence operation where the large collecting surface of long counters is required but an intense background field is unavoidable. Following the fundamental work of Simpson (1)[2] numerous investigators (2–5) have succeeded in reducing this limitation. However, it continues to be one of the problems associated with this versatile instrument. The procedure to be discussed here greatly increases the rate at which a counter may be operated without loss and achieves an equally great increase in tube life. The increase in rate and life both depend upon tube length. Thus for a given percentage loss, a 40-cm. counter can be operated at forty times its usual rate, while a factor of twenty is possible with a 20-cm. tube.

Fortunately the circuit is quite simple. It can be made very compact and does not lead to geometrical complications as when a number of tubes are to be used in coincidence.

Studies were made with numerous counters at this laboratory and the circuit operated satisfactorily with all of them.

Although with a multiple tube circuit operating on the same prin-

* Assisted by the joint program of the ONR and the AEC.

[1] Bartol Research Foundation of The Franklin Institute, Swarthmore, Pa.

[2] The boldface numbers in parentheses refer to the references appended to this paper.

ciple much higher overvoltages are possible, simplicity is lost. The slight gain in efficiency with marked reduction of counter life hardly justifies a complexity which discourages use. Such a procedure after test was abandoned in favor of the simple arrangement discussed here.

THE CUT-OFF CIRCUIT

The main circuit shown in Fig. 1 is labeled Cut-Off Circuit. It is accompanied by two subsidiary circuits labeled, respectively, Viewing Circuit and Rate-Measuring Circuit. These subsidiary circuits serve the purpose of facilitating the study of the cut-off circuit. The cut-off circuit itself is coupled directly to the wire of the counter. Since the high potential is applied to the cylinder of the counter at the point A, the cut-off circuit is at normal voltage levels.

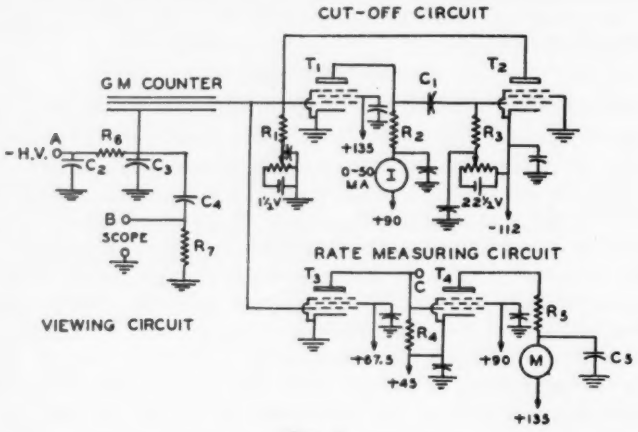

FIG. 1.

All tubes are 6AK5's and all unlabeled by-pass condensers are 0.0025 microfarads.

$C_1 = 50\mu\mu f$	$C_2 = 0.1\mu f$	$C_3 = 400\mu\mu f$	$C_4 = 4000\mu\mu f$	$C_5 = 1.0\mu f$	$R_1 = 1800$
$R_2 = 2700$	$R_3 = 2200$	$R_4 = 1000$	$R_5 = 3300$	$R_6 = 47{,}000$	$R_7 = 100{,}000$

When an ionizing particle passes through the counter, it starts the normal spreading process down the wire from which we obtain the "electron component" (6, 7) necessary to actuate the circuit. When the voltage pulse appearing across R_1 is approximately 0.2 volts, it is amplified enough in T_1 to cause the grid of T_2 to come from below cut-off bias; hence, the plate current of T_2 adds to the voltage drop of R_1—a cumulative action which proceeds until T_1 is cut off. The grid of T_2 starts to recover rapidly by virtue of the short time constant determined by C_1, R_2, R_3 and the input impedance of T_2. As the grid of T_2 recovers, the plate current of T_2 decreases until the voltage drop across R_1 is less than the cut-off bias of T_1. The resulting negative pulse on the plate of T_1 abruptly returns the grid of T_2 below its cut-off value. The time required for an entire cycle of the circuit operation is approximately

1.5 microseconds: after this period the circuit is again ready to accept a new pulse.

In order to make the circuit operate as rapidly as possible, the stray capacitance must be kept at a minimum. Tubes T_1 and T_2 (Western Electric 6AK5's) were mounted adjacent to each other and

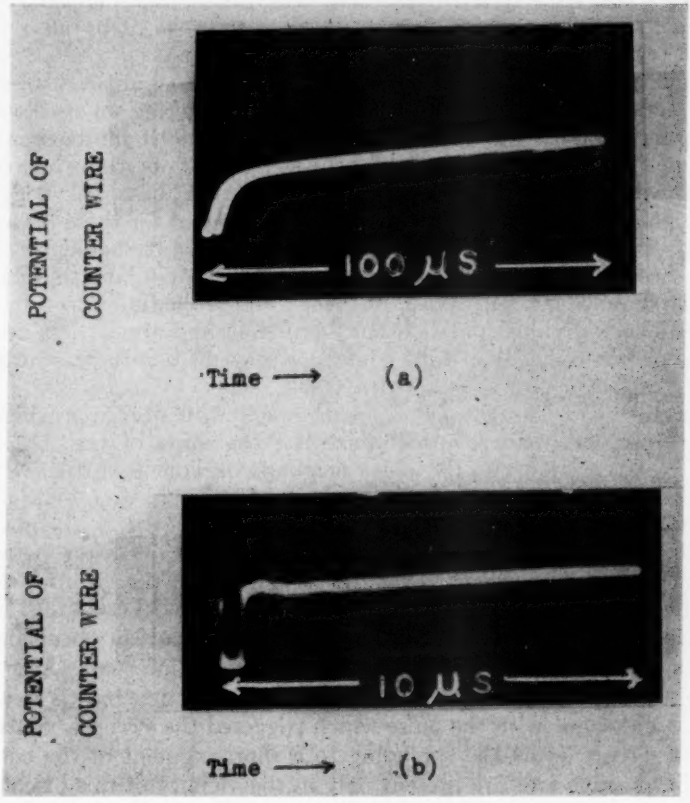

FIG. 2.—Presentation of dead-times.

(*a*) Normal counter discharge.
(*b*) Same counter discharge with cut-off circuit operating. Only saturated pulse bottoms are visible in (*b*).

connections were soldered directly to the tube pins. T_1 and T_2 were chosen so that with plate voltage = 45V, screen grid voltage = 67.5V, and control grid voltage = − 5.0V, the plate current was less than 0.2 μa. However, in the actual circuit, these values were increased.

The circuit output pulses were found to be uniform in shape and amplitude up to the highest rates encountered—2×10^5 counts per second. However, at very high rates of counting, resistor R_6 should be short-circuited so that the potential across the counter remains

constant. No alteration in size or shape of the pulses was observed over the operating range of counter voltages used—from six to thirty volts above the starting potential. In virtue of this fact, the pulses appearing across R_1 may be applied to a rate measuring circuit consisting of T_3 and T_4. The current through meter M served as a rate indicator. Obviously, at the higher rates, the fluctuations in M were quite small. The resistor R_5 was added so that the plate pulse of T_4 would trigger a scaler directly for calibrating purposes.

Figure 2 shows the results of the method used to find the dead-time. The method, due to Stever (8), consists of triggering an oscilloscope sweep by a counter pulse, delaying the pulse so that it can be seen at a fixed position near the beginning of the sweep, and observing any other pulses which occur in the interval of the time base. A triggered oscilloscope connected at point C (Fig. 1) was used for these presentations. Photons were used to initiate the pulses. It should be noted that these photographs are time exposures so that a large number of triggering pulses are superposed at the left end of the time base; whereas subsequent individual pulses occur at random and appear less intense in the photograph. The same counter was used for both presentations of Fig. 2.

In the upper photograph no pulses appear until after approximately 45 microseconds have elapsed[3] since the beginning of the triggering pulse. After this time, the pulse height is dependent upon the time since the triggering pulse has occurred. The manner of build-up of pulse sizes in this region can be correlated to the motion of the positive ion sheath in the counter after the discharge. Although the potential of the wire is returned to normal in a short time, the electric field is still being partially controlled by the ion sheath.

The case of Fig. 2*b* is different. With the circuit in operation, no pulses were observed in the first 1.5 microsecond interval. After this time pulses appear, and any pulse appearing on the time base is identical in size and shape with the pulse which triggered the sweep.[4] Since the cut-off circuit limits the spreading to a short segment of the counter length, positive ions are present only in the vicinity of this discharged region. When the circuit returns the potential of the counter to its normal value, the electric field near the wire is returned to normal also, except for the short segment used in the previous discharge.

The auxiliary viewing circuit connected to the counter cathode is designed in such a way that the pulses at point B (Fig. 1) are proportional to the number of positive ions evolved in the counter discharge. The ratio of the pulse heights observed at B with and without the

[3] The vertical descents of the pulse traces are invisible on the photograph on account of the rapidity of the sweep.

[4] Again, on account of the rapidity of the sweep, only the lower parts of the pulses are represented. They correspond to the thickenings on the faint, approximately horizontal line.

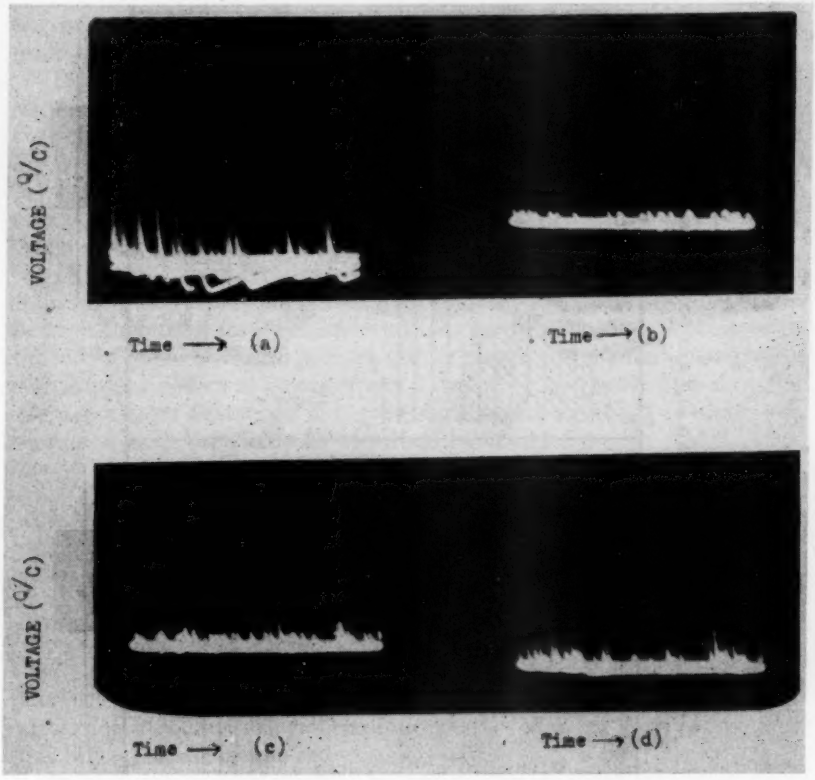

FIG. 3.—Observations from cylinder of counter.

(*a*) Normal discharge from photons.
(*b*) Discharge from photons with cut-off circuit operating.
(*c*) Discharge from β-rays at side window of counter with cut-off circuit operating.
(*d*) Discharge from β-rays at end of counter with cut-off circuit operating.

circuit in operation (Fig. 3*a*, *b*) indicates that the circuit limited the spreading of the discharge to 1/20 of the length of the counter or approximately 1 cm. If two centers separated by more than 1 cm. are formed by an ionizing particle, a pulse larger than a single center pulse may be produced. In Fig. 3*c*, β-rays were sent in through a side window in the counter and scattered β-rays produced some of these multiple centers. The effect of more starting centers (or multiple centers) is shown more clearly in Fig. 3*d*, where the β-rays were admitted through an end window.

INVESTIGATION OF EXTENT OF SPREADING

In order to check the previous assumption that the spreading process was limited to approximately 1 cm. of length, a special counter with the cathode split into a number of individual cylindrical segments was

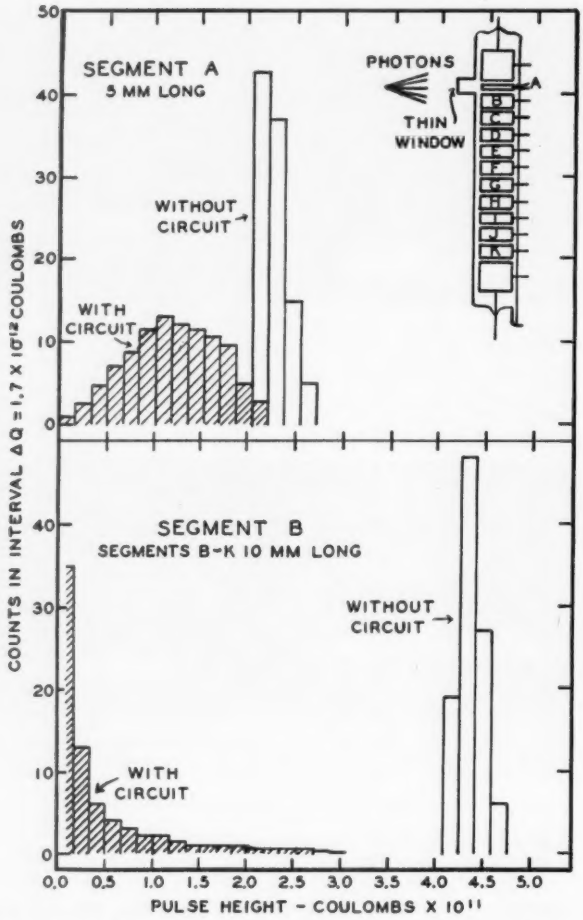

FIG. 4.—Pulse height distributions from cathode segments along the counter length showing the effect of the cut-off circuit.

used (Fig. 4). Opposite to segment *A* was a thin window which admitted photons so that a single-centered discharge always started in the vicinity of segment *A;* hence, the spreading started from this region. The experiment consisted of measuring the distribution of pulse heights on different segments under two conditions: with and without the cut-off circuit. The results of these tests are shown in Fig. 4. Without the circuit, the pulses appearing on segment *B* are about twice as large as those on segment *A*, as may be seen from the plain block pulse height distribution. This is to be expected from the relative lengths of the two segments (10 mm. and 5 mm., respectively).

Segments C through K had distribution curves, without the circuit operating, similar to that shown for segment B.

With the circuit in operation, the pulse-height distributions on all segments of the counter are markedly changed. While the counting rate of segment A remained unchanged, that of segment B was reduced by approximately 25 per cent and that of segment C by more than 99 per cent of the "no-circuit" rate. This constitutes evidence that the circuit limits the spreading to not more than 1 cm. from the point of origin of the discharge.

The rather broad pulse-height distribution observed on segments A and B is believed to result mainly from poor collimation of the photon beam rather than statistical fluctuations in the spreading process or in the cut-off time of the circuit. Comparison of the shaded pulse-height distributions observed on segments A and B (Fig. 4) indicates that the average charge developed along the length of segment B is much less than in A with the circuit in operation.

COUNTING RATES

If N' is the number of impulses which should be counted per unit time, and N is the number actually counted per unit time, the relation between N and N' is

$$N = \frac{N'}{1 + N'\sigma},$$

where σ is the dead-time. The formula is based upon the assumption that the counter and associated circuit are completely incapable of registering a count during a time interval σ following each count, and that full efficiency is restored abruptly at the end of the interval σ.

In order to obtain equally spaced values of N', five radioactive sources A, B, C, D, E were used. The plan was first to find positions for these sources in which each individually gave the same value for N. We are then assured that the use of A, followed by the use of A plus B, followed by the use of A plus B plus C, etc., provides successively equal increments of N'. If we set $N' = \alpha n$ where n is the number of sources irradiating the counter, we have

$$N = \frac{N'}{1 + N'\sigma} = \frac{\alpha n}{1 + \alpha n \sigma}. \tag{1}$$

Now with source A alone in position, it was found that $N = 10^4$ cps. Hence

$$10^4 = \frac{\alpha}{1 + \alpha\sigma}$$

$$\alpha = \frac{1}{10^{-4} - \sigma}.$$ **

** It may be remarked that 10^{-4} seconds is the greatest value for σ consistent with the measurement of 10^4 counts per second.

Now Eq. 1 yields

$$N = \frac{\left(\frac{1}{10^{-4} - \sigma}\right) n}{1 + \left(\frac{\sigma}{10^{-4} - \sigma}\right) n} = \frac{n}{\sigma(n - 1) + 10^{-4}}. \qquad (2)$$

Substitution of the values $\sigma = 1$, 10 and 90 μ-sec. into Eq. 2 yields the set of dashed curves shown in Fig. 5. As the theoretical curves are

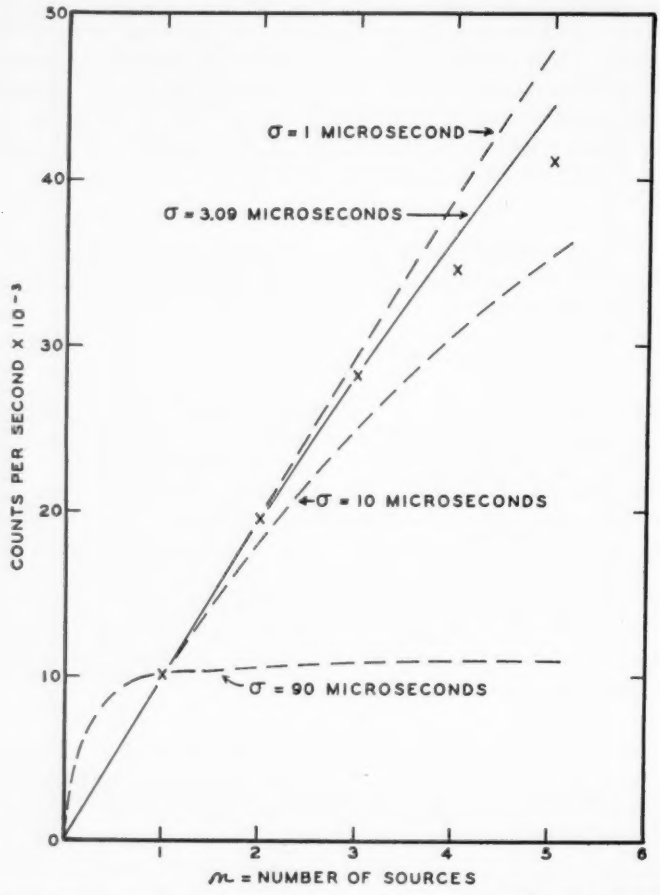

FIG. 5.—Counting rate for counters of various dead-times as a function of source strength. A unit of source strength is defined as that strength required to give 10^4 counts per second. This unit of source strength is given by $\alpha = \frac{1}{10^{-4} - \sigma}$. The X's are experimental points obtained with the cut-off circuit operating.

plotted in Fig. 5 it might appear that at low source intensities the counter would count faster with a 90 μ-sec. dead-time than with a 1 μ-sec. dead-time. This apparent absurdity arises from the fact that the method used to normalize the theoretical curves to the experimental data yields a different value of α for each dashed curve. The solid curve, which fits the experimental data for $n = 1$, 2, and 3 within the statistical errors, is obtained by setting $\sigma = 3.09$ μ-sec. The agreement of the solid curve with the experimental data is as good as might be expected[5] in view of the limited extent to which Eq. 1 is applicable to the experimental conditions.

EFFICIENCY AT LOW OVERVOLTAGE

Because it has been generally believed that the efficiency of G-M counters is low near the starting voltage,[6] and since the present experiments were carried out at relatively low overvoltages, a measurement

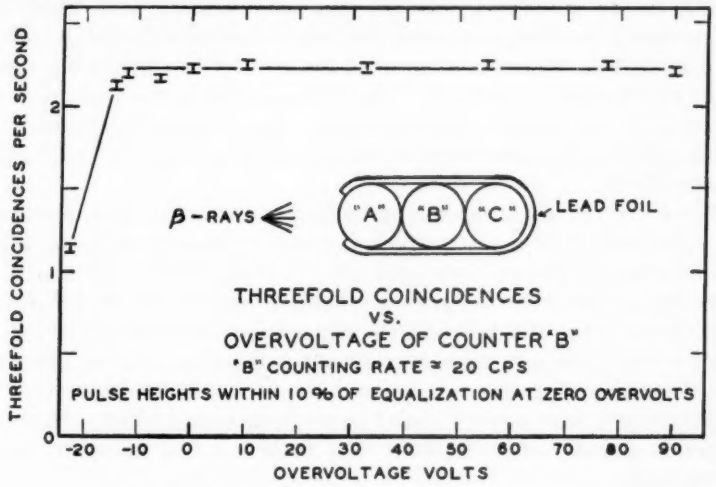

FIG. 6.—Relative efficiency of counter *vs.* overvoltage.

of the relative efficiency of the counter as a function of overvoltage was made in a triple coincidence arrangement. The results shown in Fig. 6 indicate no loss of efficiency at the voltages used in these experiments.

COUNTER DESCRIPTIONS

While most of the work reported here was done with tubes 20 cm. long and 1 cm. in diameter, studies included the use of counters varying

[5] This value of σ calculated from the experimental observations is too large. The reason for this is that the first source was very near to the counter, saturating that portion immediately adjacent to it and decreasing the effective length of the counter for counting the radiations from the remaining sources which were placed at successively greater distances.

[6] The ambiguities associated with the definition of starting voltage in self-quenching mixtures are now under investigation

in length from 8 to 40 cm. and in diameter from 0.9 cm. to 3 cm., all equipped with central wires 0.003 in. in diameter. Cylinders were either of copper 0.005 in. thick, or, where thin walls were desired, of Aquadag painted internally on glass walls of thickness 0.006 in. Thin windows were provided for the transmission of light where single centered discharges were essential. Gas mixtures were either argon-ether (6.5:1) at 5.5 cm. Hg pressure or argon-butane (6:1) at 8.5 cm. Hg pressure. The circuit operated effectively with all of the above counters without alteration.

SUMMARY

A two tube feed-back circuit, triggered about 10^{-8} seconds after the initiation of the discharge, interrupts the spreading process in a few hundredths of a microsecond by field reduction at the wire. The control circuit recovers, restoring normal operating field conditions except over a small segment near the point where the discharge started. Thus in about a microsecond most of the counter is resensitized, resulting in a very short dead-time. The voltage pulse on the wire, although triggered by the initial counter current, has a shape determined predominately by the parameters of the cut-off circuit and hence all pulses are equalized.

Since the circuit limits the spreading of discharge, the number of ion pairs formed in a discharge is decreased, consequently the life of the counter is greatly increased (9). Life is further increased by operating at low overvoltages for a similar reason. It should also be remembered that the velocity of propagation of discharge along the counter wire increases with overvoltage and hence a faster operating circuit capable of giving a larger reduction of field at the wire of the counter would be required if higher overvoltages are desired. However, efficiency measurements indicate that little is to be gained at higher overvoltage.

The single and multiple center effects observed suggest that with simple additional circuitry a counter may be rendered a directional radiation detector, and may also become capable of discriminating between various types of radiation.

Rates up to 200,000 counts per second with uniform pulse output have been achieved.

Acknowledgment

It is a pleasure to thank Dr. W. F. G. Swann, Director of the Bartol Research Foundation, Dr. G. W. McClure and Dr. C. E. Mandeville for their aid and assistance throughout this investigation.

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Catalyst Burns Odors, Saves Fuel.—Frenchborn Eugene J. Houdry, creator of the Houdry process of catalytic cracking of petroleum, has revealed a new application of one of his oxidizing catalysts. The catalyst destroys harmful and unpleasant industrial odors, burns them up completely, and thus evokes the prospect that in time the air in manufacturing centers throughout the United States will be made country fresh, promoting safer, more pleasant urban living.

At the same time, the Houdry catalyst, by more efficient combustion and recovery of heat from hitherto waste products, cuts consumption of fuel almost unbelievably. Implications for the nation's oil and coal resources, for American independence of foreign supply are vast and significant.

The Houdry catalysts are being manufactured by the Oxy-Catalyst Manufacturing Company, Inc., of Wayne, Pa., near Philadelphia. Houdry said installations are being put in, engineered or in the planning stage for half a dozen companies, including a large printing firm, a dyeing company and an oil refiner.

Each catalytic installation is tailored to meet the particular needs. In each instance, the catalytic units are set in layers, much like building blocks, in the venting stack. The number of units depends on what material has to be oxidized and how much there is of it.

The unit is made up of two thick porcelain end plates, a spacer bar of porcelain and 73 coated porcelain rods. The end plates are joined rigidly at their centers by the spacer bar after the rods have been inserted at both ends into shallow sockets in the plates. There is some play in the rods to allow for expansion and contraction during temperature change. The rods are assembled in staggered rows and are streamlined (tear-shaped in cross-section) to insure good contact with the gases, to eliminate turbulence and offer almost a negligible resistance to the passage of fumes through the catalytic zone.

The vital part of the unit is the coating, only .003 of an inch thick, on the rods. This is a film of catalytic alumina and platinum alloy applied by a special process in such a way that it remains adherent, intact and resists high temperatures and thermal shocks. The unit is five and a half inches long, three and one-eighth inches high and three inches wide.

Vulcanizing Transfers.—Production costs may be reduced in the vulcanizing industry through the use of vulcanizing transfers, which eliminate the use of printing presses and rubber stamps, by producing an indelible brand on the rubber article during the vulcanizing process. No preparation is needed. The transfers are placed on the rubber dough, in the mold, or under the press, where there is enough pressure, or they may be impressed by means of rollers, on the unvulcanized rubber strip in such operations as cable-covering. The transfer remains on the article throughout the vulcanization and is then peeled off, leaving the ink behind in the rubber. Millions of these transfers are used yearly for branding all classes of rubber products. They are available printed in white, black, silver, and several strong fast colors.

NOTES FROM THE FRANKLIN INSTITUTE LABORATORIES FOR RESEARCH AND DEVELOPMENT

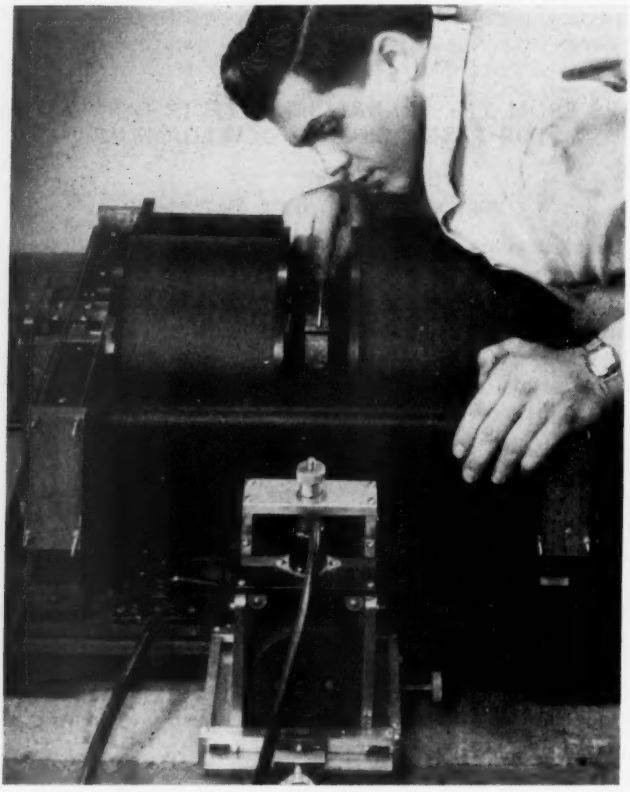
PERMANENT MAGNETIC MATERIALS

The past 20 years have seen great strides made in describing the theory underlying the behavior of ferromagnetic materials. Owing to the work of such groups as that at the Bell Telephone Laboratories in this country, and the one in France under Professor L. Neel, it has become possible to predict on fairly solid ground the sort of properties magnetic materials will possess if given certain types of treatment. In particular, this theoretical work has indicated that if the particles of ferromagnetic powders be made small enough, a great improvement in permanent magnet properties can be achieved. In fact, even such a magnetically soft material as pure iron can be made to rival all but the best permanent magnet alloys now available.

The Franklin Institute Laboratories have engaged upon a research project, under Government sponsorship, to carry further this work upon the effect of particle size on the magnetic properties of fine powders. The work of this project includes preparation of powders of the desired compositions, chemical analysis to check the composition, determination of particle sizes, binding of the powders into compact samples, and measurement and interpretation of the magnetic properties of the samples so produced.

The preparation of very fine powders of some of these alloys presents some very interesting problems. Many of the alloys melt at temperatures above 1500 C. Even after bulk samples of the required composition have been produced, reduction of the large chunks to fine powder form is difficult, if not impossible, especially since in the finely divided state many of these materials burn spontaneously if exposed to the air. These difficulties are avoided by using an entirely different approach. An appropriate inorganic compound containing the metals in the required proportion is prepared, and then the non-metallic constituents are removed with hydrogen at 400 to 600 C. The result is a fine powder of the alloy. If it is easily oxidizable, an inert protective liquid can be added before admitting air to the furnace, to prevent spontaneous combustion.

Particle sizes are determined primarily by direct measurement using the electron microscope. The information from this instrument is supplemented by measuring the surface area per gram by the well-known nitrogen adsorption technique, and by observing the degree to which X-ray diffraction lines from the sample are broadened.



Inserting a specimen in the Sanford-Bennett Permeameter (Rubicon Co.).

Solid samples are prepared by pressing the powder, together with an organic binder, in a die of the desired shape. The magnetic properties, which are those involved in the classical hysteresis loop, are measured with the aid of a permeameter designed by R. L. Sanford of the National Bureau of Standards.

The object of the work is two-fold. In the first place, the theory predicts certain relationships among magnetic properties, particle size, and other physical properties of the materials. These predictions need to be checked. In the second place, following leads from the theory, materials whose properties are superior to those now in use will be sought during the course of the work, leading to permanent magnets that are better than those now used.

A. D. FRANKLIN

NOTES FROM THE NATIONAL BUREAU OF STANDARDS*

CONSTANT-LEVEL DEVICE FOR LIQUIDS

A compact, easily constructed device for maintaining a constant liquid level in laboratory apparatus has been recently developed by D. E. Couch and Abner Brenner of the National Bureau of Standards. Although designed primarily for small installations, the leveler should also prove useful on large-scale equipment.

While several devices for maintaining a constant level of liquid in tanks are commercially available, none of these is satisfactory for use with small laboratory setups, such as electroplating baths operated at elevated temperatures. Usually they employ a siphon arrangement or make use of an electrical circuit to operate a solenoidal valve or pump. Those siphon levelers which receive water directly from the tap are not adaptable to plating baths because they siphon off part of the bath when the level is raised by the addition of a large piece of work. The electrical devices, besides being rather expensive, are not sufficiently portable for use with small baths. The Bureau's leveler eliminates many of the disadvantages of the previous types. It takes water directly from the tap, is of inexpensive construction, and can be easily moved from one installation to another.

The NBS leveler employs a water inlet and an overflow, or outlet pipe, to maintain a constant head. A mercury valve, attached to a float, allows the water to flow into the bath if the bath level is lowered and prevents flow outward when the level of the bath rises.

The device takes the form of a vertical tube with inlet and outlet connections near the top. Just below the outlet connection the tube is sealed off except for a smaller-diameter open tube which extends below this point, connecting the upper section of the larger tube with the lower. An open cup of mercury is supported below the small connecting tube by a float which rises and falls with the liquid level in the lower section of the larger tube. When the bath level rises, the float also rises, causing the mercury cup to seal off the lower end of the small connecting tube. All of the water entering through the inlet is then rejected and is eliminated through the outlet connection. When the bath level drops, the float descends, taking with it the mercury cup, and the water runs into the bath through the small tube.

Levelers of this kind can be made in any size, for solution depths of 10 cm. or more. None of the dimensions are critical; however, the tube should be of sufficient size that it will not become clogged by the small particles of sediment that may enter with the tap water, and the

*Communicated by the Director.

mercury cup must be large enough and so centered that it will slide freely up over the small tube without touching. A convenient diameter for the larger tube is 25 mm. In order for the water to flow freely, the overflow tube should be about 2 cm. in diameter and the float should have about 3-mm. clearance with the surrounding tube.

At NBS, one of the new levelers has been used on a 6-liter bath operating at 85 C., and another has been employed with a chromium-plating bath of commercial size. Both have functioned satisfactorily for several months, maintaining liquid levels constant to within 5 mm.

CRYSTAL-GROWING TECHNIQUE

An improved technique for growing small crystals of high-melting compounds is being used at the National Bureau of Standards. In the new method, a hot-thermocouple apparatus simultaneously heats the specimen and measures its temperature, while the operator watches crystal growth through a stereoscopic microscope and manually controls the rate of cooling. The new method was devised by Fred Ordway, of the Portland Cement Association Fellowship at the National Bureau of Standards, to meet needs arising in an X-ray diffraction study of portland cement clinker. However, it should also be applicable to crystallographic studies in other fields.

An X-ray diffraction study requires a suitable single-crystal specimen. The ideal specimen should be pure, free from flaws or twinning, and sufficiently well developed that the crystallographic axes can be found from the orientation of the edges and faces. Because large size is not necessary—crystals only 0.05 to 0.1 mm. in least dimension can be used with ordinary X-ray cameras—usable crystals of many substances can be found in natural minerals or in products of manufacture. Occasionally, however, all available specimens of a mineral are either too impure or too finely crystallized, and synthetic melts of the proper composition likewise form crystals that are too small. This is true of the calcium silicates and aluminates of portland cement clinker being studied in the NBS laboratory, and it is this problem that the new technique was devised to solve.

Earlier work had indicated that single crystals are grown most satisfactorily by manually controlling the cooling of the smallest droplet that will yield a crystal large enough to be used. With a droplet of small size, the possibility of growth of unwanted crystals is minimized. Furthermore, the droplet can be observed through a stereoscopic microscope during the entire crystallization process, which may take several hours. Twins or other extraneous crystals can thus be detected and melted away as soon as they form.

The NBS technique facilitates precise control of the cooling process. A thermocouple of platinum and platinum-10 per cent rhodium is mounted under a stereoscopic microscope. The thermocouple is heated

with 5-kilocycle alternating current, supplied through a blocking capacitor. The capacitor prevents the a-c. power supply from shorting the direct-current output of the thermocouple, which is measured on an external microammeter that can be calibrated in degrees Centigrade. A small amount of the material under study is placed on the thermocouple, melted, and carefully cooled while crystal formation is watched through the microscope. Although precise control of the cooling process does not require knowledge of exact temperatures, calibration of the NBS apparatus for melting-point determinations indicates a maximum measurement error of only 5 C. in the range 770 to 1420 C.

NOTE: The crystal-growing apparatus is described in more detail in "Techniques for Growing and Mounting Small Single Crystals of Refractory Compounds," by Fred Ordway, *J. Research NBS*, Vol. 48, p. 152 (February 1952), RP 2299.

A SIMPLE MICROMANIPULATOR

A micromanipulator recently constructed at the National Bureau of Standards combines moderately high precision with simplicity, ruggedness, and low cost. Devised by Fred Ordway of the Portland Cement Association at the National Bureau of Standards, the new micromanipulator is being used with a binocular microscope to facilitate the mounting and grinding of small crystal specimens. However, it also appears to offer advantages for other uses not requiring more elaborate equipment.

Requiring little precise machining, the NBS micromanipulator consists of a heavy base plate, two adjustable manipulators for holding miniature tools, and a three-legged platform for supporting specimens in proper relation to the tools. Each manipulator consists of a triangular plate on which is mounted an adjustable column with ball-and-socket joints that can be locked in any position. Precisely controlled motion of the microtools is accomplished by means of vertical adjusting screws at the vertices of the two triangular manipulator plates.

The ends of the adjusting screw are positioned by six small blocks bearing 90° V-grooves, mounted on the base plate. In each set of three blocks, two are turned so that their grooves are parallel, and the third has its groove perpendicular to the direction of the other two. Each manipulator is thereby constrained to a single definite position at all times.

The geometry of the apparatus is such that the raising or lowering of corners of the triangles, by means of the adjusting screws, results in practically horizontal motion of the microtools in the small working region. The present model has a sensitivity of 0.08 centimeter per turn and a maximum travel of about 2.5 cm.

NOTE: The NBS micromanipulator is described in greater detail in "Techniques for Growing and Mounting Small Single Crystals of Refractory Compounds," by Fred Ordway, *J. Research NBS*, Vol. 48, p. 152 (February 1952) RP 2299.

NEW MINIATURE TEST PROBES

Two types of miniature test probes recently devised at the National Bureau of Standards are being used to speed development and testing in the NBS radar miniaturization laboratory. Light and compact, the probes are designed to cling to the test point without danger of contacting adjacent leads. Intended particularly for use with miniaturized electronic equipment, the new probes offer possible advantages for use with conventional-sized devices as well.

One of the probes is a push-on type, with a very small tapered jaw that is simply pressed onto the wire under test. The jaw is of hardened beryllium copper, silver-plated for good electrical contact. It grips the wire with a slight spring action until sufficient pull is exerted to remove it. The jaw screws into an insulating handle, made of lucite or of material like fiber having greater mechanical strength and heat resistance. The handles now being used at NBS are $\frac{1}{4}$ in. in diameter and $3\frac{1}{2}$ in. long. Color-coding of transparent-handled probes is accomplished by using colored lead wires, while colored bands are placed in grooves in the fiber-handled probes. Only about $\frac{1}{16}$ in. of the metal jaw protrudes from the insulating handle, so that the danger of shorting to nearby components is minimized.

The other probe is a lock-on type, designed so that it cannot be removed from the wire until a release button on the side of the probe is pressed. A small hook mechanism at the end of the probe remains open only while the button is pressed, and tightens on the wire when the button is released. In other respects, including size, the lock-on probe is similar to the push-on model. Like the push-on model, the lock-on probe is designed to accommodate wires varying considerably in diameter. Although several moving parts are required, manufacture of the lock-on probes is straightforward.

THE FRANKLIN INSTITUTE

COMMITTEE ON SCIENCE AND THE ARTS

(Abstract of Proceedings of Stated Meeting held Wednesday, June 11, 1952.)

HALL OF THE COMMITTEE,
PHILADELPHIA, JUNE 11, 1952.

MR. HOWARD STOERTZ in the Chair.

No. 3247: Ballantine Medal.

By unanimous vote of the Committee on Science and the Arts, duly ratified by the Board of Managers, the citation of the Ballantine report, as adopted at the meeting on March 12, 1952, was modified as follows:

In recognition of their contributions to the theory of surface states in semi-conductors and of their invention of the Point Contact Transistor, a device foreshadowing a notable advance in the means of electromagnetic communication.

JOHN FRAZER,
Secretary to Committee

LIBRARY

The Committee on Library desires to add to the collections any technical works that members may wish to contribute. Contributions will be gratefully acknowledged and placed in the library. Duplicates received will be transferred to other libraries as gifts of the donor.

Photostat Service. Photostat prints of any material in the collections can be supplied on request.

The Library and reading room are open on Mondays, Tuesdays, Wednesdays and Fridays from 9 A.M. until 5 P.M.; Thursdays from 2 P.M. until 10 P.M.; Saturdays from 9 A.M. until noon.

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MUSEUM

The number of traffic accidents is mounting annually. Control of automobile traffic is a pressing problem of every city and state in the country. The need for driver instruction has become so urgent that attention is drawn to the admirable method of driver self-education furnished by the Museum.

With the cooperation of The Atlantic Refining Company, the Museum installed The Driverater, a device for simulating driving conditions combined with an automatic recording instrument which informs the driver under test whether he or she has successfully avoided the various traffic hazards to be encountered while driving through the main street of a provincial town. It is to be observed that this is not a test of driving skill, nothing of an untoward nature is presented by the test. The incidents that call for action on the part of the driver undergoing the test are all of the kind that are constantly met with by motorists, and are primarily intended to inform the driver (or to remind him) that an unfailing vigilance is required in driving a car.

The device consists of a stationary automobile (a 1952 model was recently presented by the local Ford dealers) with the usual controls, placed before a screen on which is shown a motion picture of a conventional street scene projected by a continuous 16-mm. film projector, and the automatic recorder. The projectors (two are used to avoid delays through a possible interruption) are fitted with a micro-switch which operates the recorder.

Nine casual incidents are shown, such as a traffic light, a pedestrian who steps out from behind a bus, a driver of another car who heedlessly steps out of the left side of his car into the street, the inevitable small boy and his bicycle, and drivers who, through ignorance or discourtesy, fail to observe safe driving rules. These incidents have been presented with a great deal of skill so that their appearance on the screen is realistically rendered and provokes instinctive reaction upon the part of the driver taking the test.

At carefully measured distances are notches cut in the side of the film. There is a notch for each individual incident and, if the driver under test takes the right precautions to meet the situation in front of him on the screen, his action brings into operation the micro-switch which, through the appropriate notch in the film, makes a contact that operates the recorder. This recorder marks a card inserted in the machine when the driver takes his seat in the test car. Thus a sign of approval is marked on the driver's individual card for each incident successfully negotiated. This card is given without comment to the driver at the completion of the test. It becomes the driver's own responsibility to correct his faults by exercising more care in anticipating in real life the nature of the incident which took him by surprise in the motion picture.

The popularity of The Driverater is demonstrated by the line of visitors patiently awaiting their turn to take the test on a busy day. The driver's seat in the test car is rarely unoccupied even when attendance at the Museum is slack. The fame of The Driverater is widespread. Inquiries from numerous quarters have been received requesting information upon the operating details from persons who wanted a similar device for driving instruction, for grading professional drivers, and for periodical tests of bus drivers. A recent request announced that the device was for police purposes, to test drivers involved in accidents who were suspected of being under the influence of drink! Obviously, this device has a decided value in a diversity of applications.

Every visitor to the Museum should make a point of taking this test periodically, since he will be furnished with evidence of his own alertness, or lack of it. Driving aspirants can learn much from the test. Road courtesy, the absence of which causes many accidents, could very well be improved by more frequent recourse to The Driverater. Try it for yourself next time you are here.

JOURNAL OF THE FRANKLIN INSTITUTE

The following papers will appear in this JOURNAL within the next few months:

MOON, PARRY AND DOMINA EBERLE SPENCER: Separability in a Class of Coordinate Systems.

ROBERSON, ROBERT E.: Synthesis of a Nonlinear Dynamic Vibration Absorber.

NEWTON, GEORGE, C., JR.: Compensation of Feed-Back Control Systems Subject to Saturation.

SILBERSTEIN, LUDWIK: Properties of an Exponential Size-Frequency Distribution of Finite Extent.

POLNAUER, FREDERICK F.: Bio-Mechanics—A New Approach to Music Education.

KRZYWOBLOCKI, M. Z.: On the Invariants in the Turbulence in Compressible Viscous Fluids.

HETENYI, M.: Application of Maclaurin Series to the Analysis of Beams in Bending.

MANDEVILLE, C. E., E. SHAPIRO, R. I. MENDENHALL, E. R. ZUKER AND G. L. CONKLIN: Radiations from Zr^{97} and Nb^{97}.

THE FRANKLIN INSTITUTE

exists today because of the faith and generosity of the men and women who for 128 years have given time and money to its support.

The Institute welcomes financial gifts and bequests and hopes that all those who desire to perpetuate its work will make the The Institute one of their beneficiaries.

FORM OF BEQUEST

*I give and bequeath to The Franklin Institute of the State of Pennsylvania for the Promotion of the Mechanic Arts, the sum of*_____

_____

BOOK REVIEWS

PHYSICAL CHEMISTRY OF SURFACE FILMS, by W. D. Harkins. 413 pages, illustrations, 16 × 24 cm. New York, Reinhold Publishing Corp., 1952. Price, $10.00.

No man was in a better position to write this book than the late Dr. Harkins. Over the last four decades he has contributed mightily to the study of interfacial phenomena, so much so that at the time of his death he was the acknowledged leader in this field. For this reason, the appearance of this book is an event of great importance. It is true that it is for the most part a collection of material that had already been published in his many papers, but it is here gathered together for the first time, and his work has been of such outstanding importance that the mere fact that it is gathered in one place is a great contribution to the literature of this field. To Dr. Harkins we owe the first really clear statement of the thermodynamics of interfaces. He has done a great deal to put measurements of interfacial tensions, contact angles, heats of immersion, and the surface areas of solids on a precise and definite basis. He was responsible for much of our knowledge of phase transitions in surface films, and of the theory of micelles in soap solutions. Coming as it did at the end of his life, this book can be said to summarize his work in the field of surface chemistry. It is interesting to remark, in passing, that great though his contribution has been in this one field, it does not represent all of his work. It was some time before this reviewer could really believe that the Harkins who was contributing materially to nuclear studies was the same Harkins whose work was so outstanding in surface chemistry.

As for the book itself in detail, it consists of six chapters, five of which are lifted quite bodily from Dr. Harkins' papers, and the sixth of which was written specially for this book by E. J. W. Verwey. The first chapter, the nature and energetics of surfaces, contains a general collection of ideas on surface forces, orientation of molecules in surfaces, thermodynamics, etc. The second chapter, on the spreading of films on liquids, deals with the thermodynamics involved in the formation of various types of films; the area-force relationships; the existence of phase transitions in these films, etc. The third chapter, the subject of which is films on solids, takes up adsorption from vapors and liquids on solid surfaces; phase transitions in these films; thermodynamics of the formation of these films, including the heat of immersion; contact angles; and the formation of monomolecular films on solids. In the fourth chapter a brief description is given of the theory of micelles and solubilization in soap solutions. The fifth chapter discusses the chemistry of emulsion polymerization, and the sixth is Verwey's chapter on the electrical double layer and its role in the behavior of lyophobic colloids.

The importance of Dr. Harkins' work is such that there is no need to write a critical review of the contents of this book. Special attention may be called to the treatment of the thermodynamics of the spreading of films on liquids and solids; to the discussions of the experimental techniques in the measurements of interfacial tensions and heats of immersion, which are excellent; and to the general way in which Harkins has tried at every turn to give a unifying physical picture, either in terms of molecules or thermodynamics, to the phenomena with which he is dealing.

There remains only then to discuss the arrangement and general construction of the book, which unfortunately are not good and mar an otherwise very excellent book. Much of the material is presented in a scattered fashion and jumps from subject to subject, often repeating itself or introducing a new subject with insufficient description of the system or situation that is being discussed. This lack of unity must be laid to the fact that the book consists really only of a collection of Dr. Harkins' papers, apparently cut as one might a movie, and fitted together as well as possible. It is unfortunate that Dr. Harkins could not have rewritten more of the material so as to make a more unified book. The explanations are not always clear, since at times he delves into completely irrelevant matter (describing the electronic structure of the atom when he is talking about intermolecular forces), and at other times he takes for

granted that the reader knows all about the details of the systems he is discussing, and talks only of the final picture. An example of this neglect can be found in his discussion, on page 71, of the capillary height method of determining surface tensions. During this discussion he talks about the contact angle of various liquids, implying but not stating directly that these are contact angles against glass. The beginner might easily come away with the idea that the contact angle is a property of the liquid alone and does not depend on the solid surface involved.

All in all, this is an excellent book for the initiate in the field of surface chemistry, and is one that no worker in this field should neglect. It is, on the other hand, definitely not the kind of a book for a beginning student to use as an introduction or even a survey of the field. Unless the reader has a fairly good general knowledge of the subject, he is bound to be confused by the many places in which Dr. Harkins has simply left unsaid details of his subject that are really important.

A. D. FRANKLIN

THE PLANETS, THEIR ORIGIN AND DEVELOPMENT, by Harold C. Urey. 245 pages, diagrams, 16 × 24 cm. New Haven, Yale University Press, 1952. Price, $5.00.

A revolutionary, new and controversial approach to the cosmogonical problem is offered by one of the most astute scientists of today. Dr. Harold C. Urey, Distinguished Service Professor of Chemistry at the University of Chicago and a Nobel Prize winner, has a background which commands the utmost respect for his new ideas.

The present position of Dr. Urey permits him to dabble—and this word is not used in a derogatory sense—in the sciences and bring to them a wealth of knowledge; and, by commanding the respect of his fellow men, he has the opportunity to explore the sciences under the guidance and tutelage of the keenest workers in the field. As an example of his diverse activities, the reviewer remembers Dr. Urey's paper on Paleotemperatures presented to the AAAS. Now Dr. Urey has turned his attention to one of the fascinating and speculative facets of modern astronomy—the origin of the solar system.

In his new book Dr. Urey believes the planets and other members of the solar system began as hot gases which cooled and when cold these bodies coalesced into the objects as we know them today. In a way Dr. Urey is going back through the pages of science and picking up a thread of a theory presented at the turn of the 20th century when the eminent University of Chicago scientists Chamberlain and Moulton presented the Planetesimal Hypothesis. They too imagined the metamorphosis of the solar system from cold bodies or planetesimals.

In postulating these processes the author falls in line with an increasing array of distinguished astronomers and astrophysicists in challenging the idea that the earth cooled from a mass of hot gas.

Building on this the author attempts to show how the planetesimals (mixtures of iron and silicates) formed the earth. This porridge formed a huge mass which melted when sparked by the heat of the radioactive potassium, thorium and uranium contained in the mixture; through this melting there took place the segregation of the earth into the layers which are identified by the seismologist. The iron, being the most massive, sank to the center of the earth and the lighter rocks worked to the surface to form the crust. This settling process, he believes, is still going on today. He tries to explain the origin of the lunar craters by the impact of the planetesimals.

Some most interesting results arise from his conception of the constitution of the other planets. Here is one theory which may be capable of proof.

Within the lifetimes of some who read this review man will probably be moving through space and one way of checking on the accuracy of Dr. Urey's calculations would be to visit the moon and the nearer planets. When this is done it will be possible to determine whether Mercury is composed largely of iron and whether the moon has any iron at all and just what are the conditions on Mars and how do they compare with the conclusions of Dr. Urey. Here is a great possibility. Let Dr. Urey carry his theory forward garnering every bit of information from it and then check these conclusions in some twenty-five or fifty years. If Dr. Urey is proven right then the scientist has obtained one of the most powerful analytical tools of the century in the application of the principles of physical chemistry to the problem of the origin of the solar system.

However, until that day in the future there will be a wealth of discussion among cosmogonists and the resulting controversy will be stimulating to all the sciences.

I. M. LEVITT

PROCEEDINGS OF THE LONDON CONFERENCE ON OPTICAL INSTRUMENTS—1950. 264 pages, illustrations, plates, 14 × 22 cm. New York, John Wiley & Sons, Inc., 1952. Price, $7.00.

Included in this book are some 21 papers, by leading authorities from many European countries and from the United States, together with a brief summary of each paper in English and in French and of the discussion following the presentation of the papers. The papers are grouped under several topics as follows: Photographic and Projection Lenses (3 papers), Reflecting Microscopes (3 papers), Gratings and Grating Instruments (3 papers), Phase-Contrast Microscopes (2 papers, one in French, plus one as summary only), Spectrophotometers (2 papers, one in French, plus one by title only), Reflecting Telescopes (2 papers), New Optical Materials (one paper on synthetic crystals, one on Optical Glasses and one on Plastic Glasses), and two miscellaneous articles, one entitled "The Velocity of Light and the Measurement of Distance" and one on "Apparatus for the Photometry of Optical Instruments."

In addition to the many excellently reproduced figures, there are 12 pages of plates. The book is well organized with topics and subtopics clearly indicated, and a good subject and author index. Bibliographies are attached to most of the papers. For those interested in instrument design and for those interested in becoming acquainted with the many advances in optical instrumentation in the last few years, this book should prove most valuable.

Since it is obviously impossible to do justice to each of the subjects included in this book in a review of this length, a representative paper is chosen, namely, "A Family of Catadioptic Microscope Objectives," by David S. Grey of the Poloroid Corporation, U. S. A. Interest in the ultraviolet and infrared absorption spectra of microscopic areas has stimulated the design of reflecting or catadioptric systems to achieve a common focus for all wave lengths of light. The essential features of the Schwarzschild and Newtonian systems are described. The author presents modifications of these for use in the visible and ultra violet regions, making use of refracting elements of quartz and fluorite, which form a magnified and achromatic but virtual image of the object which is converted by spherical mirrors to a real image. The aberrations of both the lens systems and the mirrors are large but mutually compensating. In the infrared region, satisfactory objectives are in use consisting of spherical mirrors alone, since at longer wave lengths there is a larger tolerance of optical design.

RACHEL FRANKLIN

THE ATMOSPHERES OF THE EARTH AND PLANETS, edited by Gerard P. Kuiper. Revised edition, 434 pages, diagrams, plates, 17 × 25 cm. Chicago, University of Chicago Press, 1951. Price, $5.50 (paper cover), $8.50 (cloth cover).

The revision of this important group of papers has introduced enough new material to justify a notice in these pages. Sources and data available to authors up to about Februrary 1, 1948 were included in the first edition while this current one, where additions and changes were made, represents the state of knowledge two years later.

The original symposium was held at Yerkes Observatory in September 1948. That it was held at all indicated a swing in astronomical interest back toward our world and its neighbors. In the forefront of this renewed attack on comparatively local problems has been Dr. Gerard P. Kuiper, the editor of the volume and recipient of the Rittenhouse Medal of the Rittenhouse Astronomical Society at the April Stated Meeting of The Franklin Institute. The pace he has set in solar system researches is responsible in part for the necessity for a revised edition.

It may be useful to list the additions and revisions to see what kind of advances are being made in our knowledge of the planets including astronomical aspects of our own, or resident, planet:

Information recently obtained in V-2 flights about our upper air and the X-ray spectrum of the sun.

Identification of the strong red and infrared emissions of the night sky as due to the disintegration product of ascending water vapor, OH.

A new determination of the cosmic abundances of the chemical elements.

A derivation of the ozone temperature in the upper stratosphere.

A determination of the age of meteorites from their argon content.

A discussion of the presence of nitrous iodide in the lower atmosphere and its connection with the life-cycle.

A reconstruction of the conditions that led to the escape of the "protoatmosphere" surrounding the earth before the development of our present atmosphere.

A new section on the Jovian planets, giving theoretical model atmospheres that appear to account quantitatively for the known properties (composition, temperature, cloud layers) of these planets.

A development of the atmospheric conditions of Mars on the basis of new evidence and a critical examination of the hypothesis that the green areas on Mars represent plant life.

To the uninitiated the above is a bad jumble of seemingly unrelated material, but on analysis it is found that much of it is fodder for the mills of those who are grinding away at the basic question "How did the planets happen to come into being and develop as they did?"

It is this very kind of material which has made it possible for Harold C. Urey to write *The Planets, Their Origin and Development* (reviewed in this issue of the JOURNAL). A Nobel Prize chemist, he found that astrophysical knowledge had progressed to the point where the data on the planets justified a full-dress treatment along chemical lines.

Kuiper himself has carried on and his chapter "Planetary Atmospheres and Their Origins" is here expanded to 100 pages and forms a significant link in the important series of papers documenting his theory of the origin of the solar system. It was on this he reported at the April Stated Meeting and the first integrated account is scheduled for publication in the JOURNAL.

The appeal to the average Institute members of this volume is small. However, it can be suggested for perusal in the Library, rather than ownership, by those who wish to see some of the brilliant bits of research that have been fitted into the exciting new concepts of the probable birth and first 3 billion years of our earth.

Particularly recommended as on the lighter side is *The Upper Atmosphere Studied from Rockets; Research Programs* by Jesse L. Greenstein of Mt. Wilson and Palomar Observatories.

JOHN W. STREETER

ELEMENTS OF WAVE MECHANICS, by N. F. Mott. 156 pages, diagrams, 15 × 23 cm. New York, Cambridge University Press, 1952. Price, $3.75.

"Elements" is designed for students who desire a fundamental text on wave mechanics. It is intended for students in the final year of an honors course in experimental physics and also as an introduction to more advanced textbooks for those who intend to specialize in the subject.

With such readers in view, the author has chosen to omit a great deal of mathematical development that can be easily found elsewhere. Sufficient references and footnotes together with a bibliography at the end of the book will enable the serious student to obtain a more rigorous treatment of the material presented.

The text builds up the elementary theory from experimental facts and shows how simple problems can be solved. It presupposes that the reader has more than an elementary acquaintanceship with the calculus, vector analysis, differential equations and classical physics. The first chapter is a review of mathematical procedures that are most useful in solving problems in wave mechanics. From this platform the author proceeds to develop Schrodinger's equation and its applications; wave groups and the uncertainty principle; quantisation of single and many-body problems. The last chapters, six and seven, introduce the reader to transition probabilities and relativistic and nuclear developments.

Dispersed throughout the text is an abundant number of diagrams together with many illustrative problems. The book is easy to read and makes an ideal text for the student who has had only limited association with the subject. I believe that a very successful one semester course in wave mechanics could be presented using this text.

A. F. PETTY

PERFORMANCE OF LUBRICATING OILS, by H. H. Zuidema. 179 pages, diagrams, 16 × 24 cm. New York, Reinhold Publishing Corp., 1952. Price, $5.00.

This is an excellent text for reference for anyone directly concerned with the research and development of lubricating oils. It covers in great detail all of the important physical and chemical reactions of such oils and has an index for easy reference.

The author has viewed each reaction discussed with a completely open mind. He states all of the significant theories given to explain the various phenomena and cites experiments which have been performed to support or disprove them. Most of his subject matter is devoted to the basic molecular behavior of lubricating oils under laboratory conditions rather than to the practical end results with which the production engineer is concerned.

This is a book which will be of great interest to the theorist. Its value to any readers other than those specifically mentioned above is somewhat in doubt due to the extent of the detail.

WILLIAM GILLIAM

ELECTRIC MACHINERY, AN INTEGRATED TREATMENT OF A-C. AND D-C. MACHINES, by A. E. Fitzgerald and Charles Kingsley, Jr. 702 pages, illustrations, 16 × 23 cm. New York, McGraw-Hill Book Co., Inc., 1952. Price, $8.50.

The objectives of the text are to present a thorough picture of how electric machines work and to show the student that the underlying phenomena of torque and voltage production are the same in all types of machines. Machine operation is viewed in terms of the interaction between the magnetic fields of the rotor and the stator. This process is expanded to treat the d-c., synchronous and induction machines as special cases of the few common principles.

Two well written chapters introduce the student to basic electromechanical energy conversion principles. The authors then go on to a general discussion of machine performance and analysis. The chapters on d-c. machine performance and analysis contain a wealth of practical information. However, it is up to the reader to supply the detailed analysis to back up the information.

An example of the excellent treatment the authors give to the subjects covered in the book is the discussion on heating, the thermal limits of insulating materials and their relation to the life of the machine. The discussion shows the reader how the temperature limitations of various classes of materials affect the design and application of the machine and how by using the 10-degree half-life law machines can be designed for shorter life and higher temperatures. Since this is not intended to be a designer's guide, the thickness of insulating materials, the method of application, and the specific kinds of insulation are not discussed.

Synchronous machines, induction machines, fractional-horsepower a-c. motors, control type generators such as the amplidyne, and transformers are treated. Electrical transients in machines and systems are discussed and the text contains a chapter on the dynamics of electromechanically coupled systems. This last chapter ties in with the aims of the authors to treat the machine as a circuit element for which prescribed properties are sought.

A resume at the end of each chapter, numerous references to excellent basic papers and texts and about 20 problems per chapter help to make the book more valuable to the reader. Since the authors used the text for a period of six years before publication, it can be expected to be free from errors.

E. A. MECHLER

MECHANICS AND PROPERTIES OF MATTER, by Reginald J. Stephenson. 371 pages, illustrations, 15 × 24 cm. New York, John Wiley & Sons, Inc., 1952. Price, $6.00.

While many engineering problems may be solved by mathematics, it is always wise to understand the physical significance of the problem first. Surprising as it may seem, it is frequently easier to explain a complex problem in terms of mathematics only; the difficult part is to explain it in physical terms. However, only when a problem can be explained in physical terms is it really thoroughly comprehended. It is therefore a pleasure to find in "Mechanics and Properties of Matter" that the author emphasizes at the outset the secondary rather than the primary role of mathematics. Although indispensable in physics, mathematics is the servant rather than the master. While infrequent, there are some instances where Professor

Stephenson of the college of Wooster may have used a little more physical explanation of the subject matter.

Since the book is written for junior use in college, it is not particularly advanced. Noting the variety of subjects included, all of which could have occupied a book in themselves, it would have been impossible to do much more than thoroughly introduce each subject and treat some of its more common problems. In each of the subjects under discussion—kinematics, force and motion, work and energy, the law of gravitation, harmonic motion, motion of rigid bodies, elasticity, statics, hydrostatics and hydrodynamics, and wave motion—Professor Stephenson has followed the same format: introduction, usually including a short history of the subject which, incidentally, makes the book more interesting; explanation of basic concepts; and approximately thirty problems at the end of each chapter. The author has wisely made frequent use of problems throughout the text in order to illustrate the particular item under discussion.

E. W. HAMMER, JR.

PHYSICAL PROPERTIES AND ANALYSIS OF HEAVY WATER, by Isidor Kirshenbaum. National Nuclear Energy Series III-4A, 438 pages, illustrations, 16 × 23 cm. New York, McGraw-Hill Book Co., Inc., 1951. Price, $5.25.

This is an exhaustive discussion of the experimental techniques involved in working with deuterium and treats little in addition to that indicated by the title. Following the description (in chapter I) of the physical properties of heavy water, the methods for their measurement (including the errors involved), and comparison of the results obtained by various workers, there is a discussion of the equilibrium constants for some isotope exchange reactions involving deuterium and heavy oxygen (chapter II). This latter chapter and the final chapter in the book (VI) which discusses the natural abundance of deuterium and heavy oxygen in waters from various sources constitute the two departures from the material to be expected from the title. As is typical of the entire book the emphasis in these two chapters is on techniques and results rather than on the theoretical aspects of the subject. The chapter on exchange reactions contains the briefest of discussions of the theory of this topic.

The bulk of the book (nearly half), however, is devoted to the use of the mass spectrometer for isotope analysis. Chapter III is a detailed discussion of the techniques of mass spectrometry illustrated by photographs, numerous drawings and circuit diagrams, and even parts lists for the construction of the electronic circuits involved. The calibration and use of mass spectrometers for isotopic analysis as well as the errors which must be avoided or corrected for are also described in considerable detail although the emphasis is on a few particular instruments. The following chapter is devoted to the use of the mass spectrometer in the analysis of heavy water. The various methods, with their limitations and the precautions necessary in their application are here described with considerable detail. Finally a chapter (V) is devoted to the other methods for the analysis of heavy water of which the majority involve the measurement of density.

The outstanding feature of this volume is the wealth of detail and the profusion of graphs, tables, diagrams, equations, photographs, etc. which it contains. All of these, incidentally, are very well done. References, which are quite numerous, are given at the end of each of the six chapters. Short author and subject indexes are also included.

E. R. STEPHENS

ANTENNAS: THEORY AND PRACTICE, by Sergei A. Schelkunoff and Harold T. Friis. 639 pages, diagrams, 16 × 24 cm. New York, John Wiley & Sons, Inc., 1952. Price, $10.00.

Until about ten years ago antennas for communications purposes consisted of wires suspended above the conducting earth, and the texts describing their operation were comparatively simple. Generally antennas were treated in a chapter or so forming part of a book on radio engineering. However, with the utilization of more and more of the electromagnetic spectrum for communications purposes, it has been found that the variety of forms given to antennas may be very great.

In particular the development of means for generating and using centimeter waves has stimulated much theoretical and practical work resulting in antennas whose radiation charac-

teristics are more directional than was practical with the longer wave lengths. In other words, it is clear that the developments in this field were fostered by the growth along lines other than those relating directly to antennas.

It will be of interest to the electrical engineer to know that Schelkunoff and Friis have written a comprehensive book on antennas covering all practical forms that are in use today. This includes types ranging from the basic rhombic antenna used in communications to the newer types employing electromagnetic horns, wave length lenses, and slots.

Roughly half of the book is devoted to the general theory of propagation relating to antennas and the remainder to specific applications pertaining to particular antenna types. The mathematical relations for determining antenna characteristics in terms of current distributions and the physical means for producing the desired currents are presented in convenient form. The broad experience of the authors with both theoretical and practical antenna problems has produced a text in which it is difficult to find an omission of any importance. To reiterate the many aspects of antenna design covered by this volume would be to make a very long list of subjects constituting a complex index for the stated field. This is certainly the most up-to-date book on the general subject of antennas, and it is recommended either for teaching or for engineering reference.

C. W. HARGENS

CYBERNETICS. TRANSACTIONS OF THE SIXTH CONFERENCE, edited by Heinz von Foerster. 209 pages, 16 × 23 cm. New York, Josiah Macy Jr. Foundation, 1950. Price, $3.50.

TRANSACTIONS OF THE SEVENTH CONFERENCE, edited by Heinz von Foerster. 250 pages, 16 × 23 cm. New York, Josiah Macy Jr. Foundation, 1951. Price, $3.50.

TRANSACTIONS OF THE EIGHTH CONFERENCE ON CYBERNETICS, edited by Heinz von Foerster. 240 pages, 16 × 23 cm. New York, Josiah Macy Jr. Foundation, 1952. Price, $4.00.

The Josiah Macy Jr. Foundation has had the experience over the years that the advancement of research is aided by the facilitation of communication between the various pertinent scientific disciplines. Cybernetics poses a most difficult interdisciplinary communication problem in that it is the study of control mechanisms in biological and social systems. As a consequence, it is necessary to provide a common language for the psychologist, psychiatrist, social psychologist, biologist, mathematician, physicist, and engineer. The method which the Macy Foundation uses to achieve this interdisciplinary communication is to gather together eminent research scientists in the various pertinent fields of study and to present a written version of their prepared symposium papers together with a record of the ensuing discussions. Although this method leaves much to be desired with regard to the logical outline of the field of inquiry, the method is admirably suited to the purpose for which it was chosen—the presentation of advanced notions on the course of research and the laying bare, as it were, of the process of creativity in science. The conferences have been graced at one time or another by the presence of the following persons familiar to students of mathematics and the physical sciences: Heinz von Foerster, Norbert Wiener, J. H. Bigelow, Walter Pitts, John Von Neumann and Claude E. Shannon. The biological studies have been represented by persons of comparable level of attainment. Since the various symposium papers are only loosely related in that they are oriented toward the study of cybernetics, a critical summary is not feasible. It can, however, be noted that a general trend of the meetings is the examination of mathematical models which were found useful in the physical sciences in order to ascertain their applicability to the study of the life sciences. The most recent symposium focusses interest on the technique of communications engineering and in particular on information theory.

EZRA S. KRENDEL

MECHANICS OF VIBRATION, by H. M. Hansen and Paul F. Chenea. 417 pages, illustrations, 15 × 23 cm. New York, John Wiley & Sons, Inc., 1952. Price, $8.00.

Based upon an elementary course in dynamics, this new textbook presents the basic principles of the mechanics of vibration at a level primarily for undergraduate engineering students, although the book may be used as part of an introductory graduate course in this

subject. For practicing engineers who feel the necessity of reviewing the subject matter, this book can very well serve the purpose.

The fundamental theory of vibration is presented in three sections: steady state vibration of systems having one degree of freedom; systems of several degrees of freedom; and a group of special topics including non-linear systems. The authors have been concerned with presenting the text material in such a way that the reader soon acquires the necessary confidence which allows him to set up the equations of motion for the various systems studied, from basic principles. In many cases special details of examples are avoided since the major interest is to consider illustrative problems as vehicles to demonstrate the theory and general techniques.

Single degree of freedom systems cover free and forced vibrations, with and without damping. Equations of motion are developed and their solutions are applied to numerous combinations of springs, torsion systems, shafts, and pendula. Two methods of analysis are applied to systems of several degrees of freedom: the classical method, in which the differential equations are set up from consideration of the motion of the component parts or from LaGrange's equations, including potential energy and dissipation functions; and the mobility method, in which the concepts of impedance and vector notation play an important part. Worked-out examples which demonstrate the principles involved include: a bell and clapper system; open, closed, and branched systems of springs and shafts; and systems having multi-dimensional motion, such as levers and spring-mounted platforms. The Holzer method and the Graeffe root squaring method are described in detail, and are offered as convenient methods to solve for the roots of a high order algebraic equation, such as is usually encountered in the determination of the frequencies of vibration in a complex vibrating system.

Armed with the background described above, the reader is next presented with some special vibrating systems, whose equation of motion reduces to the one dimensional wave equation, and which is solved by the separation of variable technique. Transient driving forces such as the unit step and unit impulse are introduced, as is the Dribanill integral formula for determining the full system response to a driving force when the response to these unit driving forces are known. Problems in nonlinear mechanics include the pendulum with large oscillations, backlash as part of a restoring force, and non-linear damping.

Each chapter has a collection of most interesting problems, many with answers. This should be particularly welcome to a reader who is reviewing or learning the material for the the first time outside of a formal class. The text is highly recommended for all engineers who wish a review of fundamentals.

S. CHARP

MUSICAL ENGINEERING, by Harry F. Olson. 369 pages, illustrations, 16 × 24 cm. New York, McGraw-Hill Book Co., Inc., 1952. Price, $6.50.

In the words of the author, this book presents "a description and exposition of the processes, instruments, and characteristics involved in all the steps from the musical notation on paper to the ultimate useful destination of original or reproduced sound, the human hearing mechanism." The physics and the applied aspects of musical instruments, sound-reproducing systems, and room-acoustics are given the fullest treatment of all subjects in this book. The shortest chapters are devoted to the subjects of musical scales, musical terminology, sound waves, and the properties of music.

In his attempt to provide a handbook for many different groups of specialists and amateurs in the various fields of making music, the author often sacrifices completeness for the sake of variety. The specialist in one field may learn more about the other fields than about his own. When he examines the material referring to his own field, he is likely to find debatable definitions, incomplete descriptions, or occasional errors. For example, the air-siren, the music box, and the metronome are classified in the group with electrical musical instruments; the description of the function of a piano's center pedal does not apply to all pianos and does not precisely describe the function where it is intended to apply. The reviewer feels that a handbook of this scope should be written by a group of specialists representing the various fields.

One purpose of this book is to stimulate the development of electrical and electronic musi-

cal instruments. The author suggests that the techniques of musical engineering may be used to develop instruments that are easier to play and more satisfying to hear than are present-day instruments; and that new music should be written to exploit more fully the capabilities of the human ear. It remains to be seen whether after eliminating the objectionable features in present-day instruments other features objectionable to the performer or the listener have taken their places. It is possible that the spirit of the music will be conveyed in spite of the mechanical features, just as it has for centuries.

W. W. FELTON

COLOR IN BUSINESS, SCIENCE AND INDUSTRY, by Deane B. Judd. 401 pages, diagrams, 15 × 24 cm. New York, John Wiley & Sons, Inc., 1952. Price, $6.50.

Color, all around yet elusive, dominates many of the decisions which are made daily in the home, in business and in industry. Most of the choices which individuals make with respect to color, however, are made primarily on a purely psychological appeal, as perhaps should be the case. But business, science and industry have more exacting requirements on the specification, identification, and production of color, and their problems are of importance because it is their solutions which are passed along to the eventual lay consumer. Dr. Judd's twenty years of experience at the National Bureau of Standards, where he frequently encountered puzzling problems in color, are reflected in this book, which presents the subject of visual psychophysics in practically useful methods.

A first short section of the book is concerned with basic facts regarding color vision. Since so much of the individual's response to color stimulii depends upon whether the eye is normal, too much emphasis cannot be placed upon such subjects as: the structure of the eye; the interpretive elements of the system of color sight; and eye conditions which affect the observation and interpretation of a color. Chemical, physical, and psychological aspects of color are described in some detail, for the measurements of radiant energy and spectra are part of the second aspect, while color perception space and the concept of a surface color solid are part of the third aspect. This last concept is useful to industry because it forms one important basis for the establishment of a method of classifying colors using a scale which is "psychologically" spaced, that is, unit distance is a difference in color which is just perceptible to the eye.

The second and largest section of the book describes tools and techniques which are used in science and industry to describe, identify and reproduce colors. Potential users of spectrophotometers would no doubt be very much interested in the chapter which describes, in detail, the structure, use, application, and limitations of such devices as: the G. E. recording spectrophotometer; the Beckman quartz non-recording unit; and a variety of visual colorimeters including the tristimulus, subtractive, difference, and Lovibond glass types. These devices help measure and compare certain physical properties of color. But perhaps the most commonly used specification of color is by means of comparison with color standards or color chips, since no equipment but a set of chips, a good eye, and good light is required. American industry uses many such sets of standards, which can be classified as: colorant mixture systems which show what can be done with base colorants; color mixture systems which show in the form of material standards the sequence of colors related to the adjustments on a tristimulus colorimeter or Maxwell disk system; screen plate printing color systems, for printed solid colors; and color appearance systems, which exemplify the psychological attribute of color perception. One and two dimensional color scales and nonsystematic sampling of color scales are often used in the specification of textiles, paints, printing inks, plastics and a host of miscellaneous products. These are described.

The physics and psychophysics of colorant layers are the subjects in the third section of the book. More technical discussions are concerned with the subjects of: gloss or degree of approach to a mirror surface; opacity or hiding power of a colorant layer, a subject of great importance to the paint industry; interrelations between reflectance and opacity; the identification of colorants and techniques for achieving a color match; and the formulation of colorant layers. Several tables and a large bibliography close the book.

Of three or four books published on the subject of color in the past several years, this one appears to offer the most practical suggestions to those directly concerned with color measurement and specification.

S. CHARP

BOOK NOTES

HANDBOOK OF ENGINEERING FUNDAMENTALS. Second edition, 1170 pages, tables, diagrams, 15 × 22 cm. New York, John Wiley & Sons, Inc., 1952. Price, $10.00.

The second edition of this handbook is similiar to the first, with the following changes noted: aluminum has now been added to the tables on standard structural sizes; the table on standards and symbols has been brought up-to-date; and the mks system of units has been incorporated in the tables of conversion factors. Also, the mathematical treatment has been considerably revised, with greater emphasis on determinants, vector analysis, and statistics. The fluid mechanics section has been completely rewritten, as have those on electricity and magnetism and on engineering law. Throughout, the symbols have been brought up-to-date. Engineers will find the second edition more valuable than the first.

ANALYTICAL MECHANICS FOR ENGINEERS, by Fred B. Seely and Newton E. Ensign. Fourth edition, 443 pages, illustrations 14 × 22 cm. New York, John Wiley & Sons, Inc., 1952. Price, $5.50.

The fourth edition of this text differs only slightly from the previous edition (1941), with emphasis still on the procedures used in analyzing problems in equilibrium and dynamics. Many new problems and figures enhance this latest edition. Readers familiar with former editions will find essentially the same material in the revised edition, although a few changes in sequence are noted: the discussion of first moments and centroids of geometric figures is now in the appendix; the chapters on governors and the gyroscope have been eliminated, although some of the gyroscope material has been transferred to Part III; the calculus method is introduced earlier in the work; and the general coplanar force system (rather than the simple type) is used to explain the graphical and algebraic methods of determining the resultant of a force system.

TRACTORS AND THEIR POWER UNITS, by E. L. Barger, W. M. Carleton, E. G. McKibben and Roy Bainer. 496 pages, illustrations, 15 × 22 cm. New York, John Wiley & Sons, Inc., 1952. Price, $6.50.

This is a textbook aimed to provide material on tractors for engineering students, and as a reference book for the practicing engineer in the farm equipment industry.

The authors have brought together and summarized data found in technical literature and combined this with proven principles and techniques. The internal combustion engine is carefully considered and applied to the problems of the tractor operation and performance. The material is presented in a straightforward, concise, and usable form.

SANITATION FOR THE FOOD PRESERVATION INDUSTRIES, prepared by The Association of Food Industry Sanitarians, Inc., in cooperation with The National Canners Association. 284 pages, illustrations, 16 × 24 cm. New York, McGraw-Hill Book Co., Inc., 1952. Price, $5.00.

A thorough, yet simply worded, treatment of the sanitation problems encountered in the food processing industry is offered in this practical book. Written in semi-outline style, it should prove easy to use as a reference, and should be studied by all who are engaged in food processing, especially in the canning, freezing, and dehydration industries. Problems from inspection, through housekeeping, pests, water supply, factory layout, cleaning of equipment, employee facilities, waste disposal, and laboratory aids, are all discussed in detail, with additional references given for those who wish to pursue the subject more thoroughly.

FARM POWER, by Ben D. Moses and Kenneth R. Frost. 484 pages, illustrations, 15 × 24 cm. New York, John Wiley & Sons, Inc., 1952. Price. $5.75.

Modern farming is a far cry from the days when a farmer needed only to know how to handle horses. This book, written for the college agricultural student, brings the fundamentals of power, energy, electricity, and combustion to the attention of future farmers who must know

how to repair an engine, rather than feed the horses, to get maximum production. More than half the book is devoted to various aspects of internal combustion engines, and about a third to tractors. A valuable book for the farmer who has mechanized his farm, and also for tractor operators, salesmen, service men and tractor dealers.

INDUSTRIAL FURNACES, Vol. 1, by W. Trinks. Fourth edition, 526 pages, illustrations, 16 × 24 cm. New York, John Wiley & Sons, Inc., 1951. Price, $10.00.

The fourth edition of Volume 1 brings up-to-date information of heat transfer, furnace design, and operation. The volume is divided into sections on capacity, economy, thermal efficiency, strength and durability, and movement of gases in furnaces. Much of the text has been rewritten, all calculations and tables have been changed from gross tons to net tons, and new illustrations have been included.

PRACTICAL RADIOGRAPHY FOR INDUSTRY, by H. R. Clauser. 301 pages, illustrations, 15 × 23 cm. New York, Reinhold Publishing Corp., 1952. Price, $7.50.

Written specifically for those who are engaged in planning and using radiographic inspection in industry, this practical book offers detailed information on set-up procedures, exposure factors and technique, radiograph quality, films, and film processing. It is a thorough treatment of all phases of non-destructive radiographic inspection and should be studied by all who either perform the tests or who interpret the radiographs. The publisher is to be commended on the format of the book.

ELEMENTARY HEAT POWER, by Harry L. Solberg, Orville C. Cromer and Albert R. Spalding. 624 pages, illustrations, 14 × 22 cm. New York, John Wiley & Sons, Inc., 1952. Price, $6.50.

Prepared originally (1946) as a text for an introductory course in heat power to precede a rigorous course in engineering thermodynamics, this second edition is brought out to incorporate the changes indicated by actual teaching experience. About a hundred additional pages have been added, principally embracing a fairly complete discussion of engineering units and dimensions, and of the general energy equation of the steady flow process as the first law of thermodynamics. Many problems have been revised and there are many new ones, more difficult and more comprehensive than those in the first edition. A condensed table of the thermodynamic properties of air has been added, allowing a wider range of air-compression and gas-turbine problems. Much of the material has been rewritten, and the descriptive parts have been changed to conform to the latest practices and to illustrate the most modern equipment.

A COURSE IN COLLEGE CHEMISTRY, by V. R. Damerell. 587 pages, 14 × 22 cm. New York, The Macmillan Company, 1952. Price, $5.50.

The author has written this new text for the beginning college chemistry students who are non-science majors and for non-chemists who will be taking some additional chemistry, such as home economics majors. His aim is to teach the non-chemist enough of the basic elements of the scientific method and of the chemistry of daily life to enable him to avoid chemical blunders at home and at work. The text should help to solve the difficult problem of teaching beginning chemistry to students who do not intend to major in the subject. In following out his aim, the author has used a different organization of material than that usually followed in a beginning text; he has also included several topics which do not ordinarily occur in beginning chemistry. Nine short appendices give pertinent facts useful in such a course, for example, Appendix A gives first aid measures for accidents and antidotes of poisons.

COLLEGE PHYSICS, by Robert L. Weber, Marsh W. White and Kenneth V. Manning. Second edition, 820 pages, illustrations, 16 × 24 cm. New York, McGraw-Hill Book Co., Inc., 1952. Price, $6.50.

"College Physics" in the second edition has been amplified and rearranged. The text presents basic ideas of physics for students of science and engineering. Concise explanations,

solved numerical examples, and derivations using calculus notation are given. In the chapters on atomic and nuclear physics, biographical notes and portraits of all Nobel prize winners in physics are included.

THE DEVELOPMENT OF SOME MAN-MADE FIBRES, prepared by The Textile Institute from the papers presented at its annual conference, 1951. 79 pages, illustrations, 16 × 25 cm. Manchester, The Textile Institute, 1952. Price, 12/6d.

Tracing in detail the history and development of cellulose-derivative rayons, viscose fibers, and synthetic fibers, this book consists of three papers presented at the Textile Institute's annual conference in 1951. The coverage of the subject is very thorough and well documented, including photostats of original papers and patents, photographs of early machinery and numerous literature references. The book should be of value to all persons interested in man-made fibers, whether in this country or abroad.

GENERAL CHEMISTRY, by H. G. Deming. Sixth edition, 656 pages, illustrations, 15 × 23 cm. New York, John Wiley & Sons, Inc., 1952. Price, $5.75.

First appearing nearly 30 years ago, this standard text has been much improved in its sixth edition. Some of the innovations are: in the table of contents, headings for the descriptive chemistry chapters are indented, for the use of the teachers who wish to rearrange the order of presentation; atomic structure is introduced in Chapter 4; back-paging instructions refer to review material pertinent to the subject under discussion; chapter summaries for the first seventeen chapters have been included; definitions of terms, in small type, appear throughout the text. Among the topics appearing for the first time are new compounds of silicon and fluorine, surface-active agents, and uses for the products of nuclear reactions.

DEAD CITIES AND FORGOTTEN TRIBES, by Gordon Cooper. 160 pages, plates, 14 × 22 cm. New York, The Philosophical Library, 1952. Price, $4.75.

The author, a veteran traveler, unfolds his experiences in visiting the ruins of long ago cities located in all parts of the world. He describes the cities as they look now, and interweaves the descriptions of actual ruins with thumb-nail sketches of events that took place when the cities were in their heyday. Chapters on these ancient cities are interspersed with chapters on the customs of primitive peoples still living in forgotten places of the world. Covering several continents in space and several thousand years in time, the narrative is necessarily somewhat disconnected; to all appearances, it is also completely subjective, since the author gives no references nor documentation for his statements. However, for those readers who are fascinated by archaeology, the book should be of interest as a travelogue among the lesser known ruins of the world.

NOTE: The JOURNAL wishes to note the availability, in paper editions, of the following works, some of which have been out of print for some time. Dover Publications, Inc., New York has reprinted these in paper covers for the student and the working scientist, at a modest price. Cloth bound editions are available, but the prices noted below are for the paper bound editions.

MATTER AND MOTION, by James Clerk Maxwell. 163 pages, 14 × 21 cm. Price, $1.25.

TWO NEW SCIENCES, by Galileo Galilei, translated by Henry Crew and Alfonso de Salvio. 300 pages, diagrams, 14 × 21 cm. Price, $1.50.

CONTRIBUTIONS TO THE FOUNDING OF THE THEORY OF TRANSFINITE NUMBERS, by Georg Cantor. 211 pages, 14 × 21 cm. Price, $1.25.

A PHILOSOPHICAL ESSAY ON PROBABILITIES, by Pierre Simon Laplace, translated by F. W. Truscott and F. L. Emory from the sixth French edition. 196 pages, 14 × 20 cm. Price, $1.25.

FOUNDATIONS OF HIGH SPEED AERODYNAMICS, facsimilies of nineteen fundamental studies as they were originally reported, with a bibliography compiled by George F. Carrier. 286 pages, diagrams, 16 × 24 cm. Price, $1.75.

New Magnetic Flowmeter.—A new device, called a magnetic flowmeter, for the remote measurement of molten-metal flow, has been announced by the Special Products Section of the General Electric Company.

Designed so that its sensing element is external to the flowing liquid, the new flowmeter offers maximum safety and protection where hazardous metals, such as sodium, lead-bismuth, and sodium potassium alloys, must be metered.

According to engineers of the G-E General Engineering Laboratory who developed it, one of the basic features of the new flowmeter is that it eliminates all movable parts and physical obstructions to fluid flow. It consists essentially of a permanent magnet with a pipe centered between the magnet pole faces by means of stainless-steel supports.

As the molten metal flows through the pipe, it cuts the magnetic lines of flux set up by the magnet. This generates a small directional voltage in the pipe proportional to the amount of magnetic flux and the rate of metal flow. The voltage is picked up off the pipe by two stainless-steel wires and transmitted to an instrument showing the prevailing flow rate or a recording meter providing a permanent record of flow rates.

Since any potentiometer-type indicating or recording instrument can be used to measure the millivolt output of the flowmeter, the measuring instrument itself is not normally furnished with the equipment.

The sensing head of the new device is $3 \times 5\frac{1}{4} \times 6$ in. and will accommodate flow in pipe sizes of $\frac{1}{2}$, $\frac{3}{4}$, or 1 in. A length of stainless-steel pipe $2\frac{1}{2}$ feet long is provided to assure the required cross sectional flow distribution over a wide range of installation conditions. Accuracy of the magnetic flowmeter is ± 3 per cent.

Centennial of Engineering.—Decision of the Mutual Security Agency at Washington to utilize the importance of the Centennial of Engineering, scheduled in Chicago this summer, to bring 200 leading European engineers to the United States to study American production methods, is announced by the Centennial's president Lenox R. Lohr.

The foreign group is expected to arrive in the United States well in advance of the official opening of the big engineering society convocation part of the Centennial program on September 3. During the convocation, more than 50 leading American and foreign engineering societies will cooperate in a 10-day program of joint meetings covering all important aspects of engineering and the many fields it serves.

Present plans call for the foreign visitors to spend at least five weeks in this country. They will also participate in a special two-day productivity seminar now tentatively arranged at the Museum of Science and Industry on August 31 and September 1. At the seminar, discussions will be led by outstanding American engineering authorities. The Museum is headquarters for the Centennial and will be the scene of most of its major activities, some of which began early in July.

Following participation in the Centennial convocation, the foreign group will tour America's leading cities and production centers as well as other areas with key engineering installations. Main objectives will be to give them every possible opportunity to observe American methods of design, construction and operation of engineering works, mass production and distribution, and the roles of engineers, labor and management in the productivity of the United States.

NOTES FROM THE BIOCHEMICAL RESEARCH FOUNDATION

ELLICE McDONALD, DIRECTOR

REDUCTION OF THE NUMBER OF CELLS OF THE RAT LIVER BY A PROTEIN-FREE DIET

BY

J. O. ELY AND M. H. ROSS

Consumption of a protein-free diet, or fasting, results in a loss of protein from the liver cells, a decrease in cell size, and consequently a decrease in the size of the liver with an increase in the number of cells per unit volume. It was presumed that, during short periods, the decrease in cell size alone was responsible for the decrease in the size of the liver and that the number of cells remained unchanged (1). It has been found however, that feeding a protein-free diet to rats for longer periods of time results also in a decrease in the number of cells in the liver.

Male rats of the Wistar strain were used. The control groups were fed Fox Food Blox diet (Allied Mills); the experimental groups were fed a protein-free diet (dextrose, 89 gm.; corn oil, 5.0 gm.; salt mixture, 4.0 gm.; rice bran extract "Vitab," 2.0 gm.; riboflavin, 0.2 mgm.).

In the first experiment, rats of initial equal weights were fed the diets for 20 or 30 days; they were then used regardless of the difference in final weights of the two groups. In the second experiment, control rats were selected at the end of the protein-free diet feeding period which were equal in weight to the initial weight of the protein-free diet fed ones.

The livers were removed and weighed at the conclusion of the feeding periods, and pieces were fixed in 50 per cent formol solution. Pieces of tissue from the livers of the rats of each dietary group were embedded together so that sections were cut equally thick (4 microns).

The number of cells per unit volume of the livers was determined by counting the nuclei in equal numbers of microscopic fields (10 × ocular, 44 × objective) of the sections. The ratio of the total number of cells in the livers of the protein-free diet fed rats to the number in the Fox Food Blox diet fed rats was obtained by use of the formula

$$\frac{\text{No. of nuclei per unit volume} \times \text{wt. of liver (protein-free diet)}}{\text{No. of nuclei per unit volume} \times \text{wt. of liver (Fox Food Blox diet)}}.$$

In the first series of experiments, in which initially the rats of the two groups were equal in weight, but unequal in weight at the end of the feeding period, the number of cells per unit volume was 83 per cent

greater in the livers of the rats fed the protein-free diet than in the livers of those fed the Fox Food Blox diet, but the total number of cells in the livers was only 72 per cent as great (Table).

TABLE.—*Influence of a Protein-Free Diet on the Number of Cells in Rat Liver.*

Diet	No. of Rats	Average Wt. of Rats Initial gm.	Average Wt. of Rats Final gm.	Average Wt. of Livers gm.	No. of Cells per Unit Vol.	Total No. Cells in Liver (P-F Diet) / Total No. Cells in Liver (FFB Diet)
First experiment						
Protein-free	29	153	115	4.12	1851	0.72
Fox Food Blox	29	152	263	10.43	1010	
Second experiment						
Protein-free	4	156	87	3.70	2190	0.70
Fox Food Blox	4	—	153	7.83	1490	

In the second experiment, in which the final weight of the control animals was equal to the initial weight of the protein-free diet fed ones, the livers of the latter contained 47 per cent more cells per unit volume. The total number of cells in the livers of the protein-free diet fed rats, however, was 30 per cent less than the total number in the livers of the animals fed the Fox Food Blox diet.

The protein content of the liver varies with the dietary protein intake (2). Loss of protein from the liver cells results in smaller cells and greater numbers of cells per unit volume. The results of these experiments show that the livers were reduced in size not only because of a decrease in cell size but also because of a decrease in the number of cells.

Consumption of a protein-free diet for 20–30 days was shown to reduce the total number of cells in rat livers.

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CURRENT TOPICS

Search for New Antibiotics.—In the soil beneath your feet a silent war rages. Micro-organism fights micro-organism—for food, for oxygen, for space—in short, for survival. In this struggle for existence many of these soil creatures protect themselves by producing a chemical which can kill or inhibit the growth of other organisms. This chemical we know as an antibiotic. Discovery of the antibiotics, and their application a few years ago to the war on disease bacteria, marked the beginning of a new era in medicine.

Penicillin's remarkable success launched a worldwide hunt for medicine in the soil. Today a new "prospector" searches the mountains, the river beds and the backyards for new antibiotic wonder drugs, more precious than gold, which may bring an end to diseases like polio, cancer, the common cold—the conquest of which has remained elusively beyond the grasp of medical science.

The search is a needle-in-the-haystack story. Travelers, missionaries, and airline pilots have brought back hundreds of thousands of soil samples for study. Millions of molds derived from these samples have been screened and yet, only about 300 new antibiotics have been found. Less than a dozen are considered safe enough and effective enough to be prescribed. And just five, including penicillin, are in wide clinical use.

However—and this provides medical science with the incentive for further searching—this mere handful of antibiotics has been able to halt or sharply reduce the incidence of the great majority of diseases.

These few wonder drugs, alone or in combinations, have proved effective in various degrees against such diseases as trachoma, typhus, the venereals, pinworm, pulmonary tuberculosis, meningitis, yaws, typhoid fever, the pneumonias, and dysentery, to name but a few. The antibiotic terramycin alone has been used effectively in the treatment of more than 80 diseases, many of which, just a decade ago, were in the "often fatal" category.

But the antibiotics are not limited solely to the battle against disease. Significant as their medical usefulness is, still another powerful role was destined for these chemicals. Animal nutrition experts in the universities found that the growth of poultry and livestock was markedly accelerated by feed supplements containing such antibiotics as penicillin and terramycin. New evidence of the power of the antibiotics came to light recently with the development of Terralac, a synthetic sow's milk incorporating terramycin. Little pigs fed Terralac weigh twice as much at the eight-week weaning age as sow-fed piglets. That means more meat, cheaper and faster. It is not inconceivable that this growth-stimulating property may eventually be made applicable to human needs.

Current research is also revealing the possibility of using antibiotics to solve many industrial problems that may be of bacterial, viral, or fungal origin. Antibiotics like thiolutin may be the answer to deterioration—in textiles, leather, paints, plastics, electrical equipment. Diseases of plants may also succumb to the antibiotics. The possible elimination of food spoilage presents still another challenge to the efficacy of the wonder drugs.

Where in the world do you find the "right" soil for a new antibiotic? If

there is such a thing, it's unknown. All types of soil must be tested—whether they come from India, the Arctic, or Paducah. The old adage about oil in the backyard might apply more correctly to antibiotics.

The mass detective hunt for terramycin cost Chas. Pfizer & Co. four millions in dollars and four years in time. For between dirt and drug is a careful and complicated screening process.

A pure culture of a mold is needed to produce an antibiotic but each soil sample may contain thousands of molds. The samples must be diluted with water. A drop of this water, now containing just a few mold cells, is placed in a petri dish (a small glass dish—the screening pan of today's prospector) containing agar, a Jello-like nutrient in which microbes particularly like to grow.

The petri dishes are then placed in a warm room. After a few days the dishes exhibit a rainbow hue of molds—each a potential source of a life-saving antibiotic. The possibility, however, is a slim one. A million such molds were derived from the 100,000 soil samples at Pfizer, but only one new antibiotic of top importance was discovered. Terramycin was a million-to-one shot.

The colors of the molds are, of course, clues to identity, and the promising ones can be isolated. Each individual mold is then placed in a tube with more agar and allowed to grow a while longer in the incubation room.

The culture is then removed from the agar and placed in a nutrient liquid (antibiotics can't be extracted from a solid medium). Here the mold continues to grow, and, perhaps, secretes an antibiotic into the liquid.

Then comes the important test of antibiotic activity. Just what will it do? A few drops of the culture are added to pure strains of a disease germ. *If the germ fails to grow there is an antibiotic present.* Obviously, for many "promising" cultures this becomes the final resting place, as the germ continues to grow.

But if there is an antibiotic present a culture of the mold is grown in hundreds of gallons of a liquid medium, from which is drawn off a small quantity of pure antibiotic. This is further tested, in tubes, in mice, in rabbits, in chicks. Many antibiotics fall by the way at this point. Some are too toxic, some won't work in living tissue, some turn out be previously discovered drugs (Pfizer kept turning up the older antibiotic, streptomycin).

After terramycin had progressed this far its activity was further measured against bacterial strains. Then it was produced in pure crystalline form, in which its most favorable performance could be achieved. Terramycin was isolated in pure canary yellow crystals.

At this point terramycin was produced in large quantities for distribution to a select group of doctors for clinical trials. At the conclusion of these exhaustive tests it was pretty certain what the newest wonder drug could do. Mass production processes were set in motion, and terramycin—miracle from mold—joined the life-saving mission begun a decade ago by penicillin.

New Relays for Dial Telephones.—A radical improvement in the dial telephone system's tiny "brain cells"—the high-speed switches which can pick out the dialed number from among thousands of connections in the telephone network—has been made by the Bell Telephone Laboratories, research and development organization of the Bell System.

The new switches, or relays, can operate in less than three thousandths of a second, and can control as many as 24 different functions at the same time. They are faster, more sensitive, easier to manufacture than older types, and have a life expectancy of one *billion* operations, equivalent to one operation every second for more than 30 years.

Relays are sets of tiny switches controlled by an electromagnet. In response to electrical impulses from a telephone dial, they guide a call through the nerve centers of the dial system, see that the desired number is rung, and keep the telephones connected until the call is over.

In a modern dial office in a large city, more than a thousand relays are needed for each telephone call. Relays are also the basic parts of some kinds of mathematical computers, and of the new customer long-distance dialing system being tested in Englewood, New Jersey, which enables subscribers in that city to dial directly some 11,000,000 telephones in various parts of the United States.

For many years relays have usually consisted of narrow strips of flat spring metal assembled in layers about an electromagnet. The magnet causes the contact points of the metal strips to come together or to separate so that circuits are either closed or opened, as may be desired.

In the new relays, electrical and mechanical principles of operation have not been changed, but lengths of round spring wire are used instead of flat metal strips. These wire springs are held securely and accurately in place by a plastic block into which they are molded. Gone are a number of parts and all screws which held the old style relay together. As a result, the number of parts has dropped from more than 70 to as few as a dozen.

Because of the molded construction, the new type relay will be less expensive to manufacture and easier to assemble and adjust. It also has much greater operating efficiency and longer life than the flat spring variety, is easier to maintain, and requires less power to operate. Moreover, its operation is more than twice as fast as the principal types it replaces. Because of this greater speed of the wire spring relays, dial telephone exchanges may be designed using fewer relays than formerly.

A major problem Bell engineers had to overcome was the need to measure exactly, and at very high speed, various factors in a relay's operation. For one type of measurement they adapted a machine usually used to make high quality sound recordings; for another they developed a machine which could measure magnetism at intervals of 25 millionths of a second.

The sound recording machine was used because its motion could be controlled accurately to fractions of a thousandth of an inch. With the recorder, engineers tested for the amount of wear each part could withstand, and thus learned of the need to limit rubbing motion between parts to a thousandth of an inch or less if long life were to be obtained. Considered in terms of an expected life of one billion operations, the tiny motions are equivalent to a total of about 30 miles.

The new relays will be manufactured at the Western Electric Company's Hawthorne Works in Chicago. Limited quantities will be manufactured in the next year and a half for local telephone companies to try out in service. At peak production the schedule may call for nearly three million relays a year for Bell System use. Western Electric engineers worked closely with the Laboratories throughout the entire period of the relay's development.

Fluorescent Street Light.—A new, 6-ft. fluorescent street light which provides a constant source of virtually glareless light despite temperature changes, has been announced by the General Electric Company's Lighting and Rectifier Department.

According to G-E engineers, development of this new street light should enable the United States to gain world leadership in the fluorescent street lighting field—a position that Europe now holds.

Designated Form 206, the new fixture employs four, 100 watt, "rapid start," G-E fluorescent lamps. These newly-developed lamps will light promptly—within one second after being turned on—with no annoying blink or flicker at any time throughout their lives.

Light from these lamps is reflected through a six-foot plastic housing. The entire fixture weighs about 100 pounds, and unlike other fluorescent street lights, houses its ballast, making it a compact unit.

The new street light is expected to be used in downtown areas and whiteway lighting, and can be operated on series or multiple circuits.

Maintenance-wise, the G-E fluorescent fixture has its plastic casing hinged to its aluminum hood, permitting rapid lamp replacement.

Viscometer Used in Blood Studies.—A new electronic viscometer, which simplifies many difficult or heretofore impossible measurements of the viscosity of liquids, has been developed by Dr. J. G. Woodward, at the David Sarnoff Research Center of RCA, Princeton, N. J.

Called a vibrating-plate viscometer, the RCA device has been used in studies of human blood clotting rates by doctors, who have found that instruments such as this can open new fields of medical and biological study. The tests have indicated so far, that such measurement of changes in certain physical characteristics of blood as it clots may serve to differentiate between psychotic and non-psychotic individuals.

Besides its use in blood clotting studies, the device has been used experimentally by technicians in charting the rates at which clay preparations harden in their molds, a new and valuable type of measurement in the ceramics industry. Many other possible applications can be anticipated for such apparatus in the petroleum, plastics, paint, textiles, printing, dye and other industries where precise knowledge of viscosity and viscosity changes is desirable.

The new RCA viscometer, a developmental model, can record at any range from low viscosity alcohol to high viscosity cold molasses. Its measurements are virtually instantaneous and they can be recorded over an indefinite period of time on a moving paper chart. The instrument can take measurements of a liquid whether it is in a huge vat or in a tiny container holding a quarter of a thimble full.

As designed by Dr. Woodward, the vibrating-plate viscometer consists of a thin metal disc, 0.2 in. in diameter, at the end of a metal reed less than an inch long. An electromagnetic motor causes the disc to cut back and forth through the liquid at approximately 800 cycles per second.

"The plate makes its widest swing when oscillating in air but when dipped in a liquid the swing is restricted by the viscosity," explained Dr. Woodward. "Mounted on each side of the reed are piezoelectric blocks, which generate a voltage when stress is applied to them through the bending of the reed. An alternating voltage is thus generated which is proportional to the swing,

or amplitude, of the plate. The more viscous the fluid, the more restricted the plate's vibrations are. The resulting voltages are readily determined on a vacuum tube voltmeter and simply converted to viscosity values."

Pipeline-Network Analyzer.—A pipeline-network analyzer, used in solution of problems involving pipeline flows and pressure losses in pipeline networks, has been installed by Midwest Research Institute. The McIlroy Pipeline-Network Analyzer is one of three such devices in the United States. The others are located in Washington State College and Cornell University, where the first one was installed in 1949.

This 7-ft. electronic and mechanical marvel has proven itself extremely valuable and a great time-saver, when several alternate plans are under consideration for construction, extension or reinforcement of a pipeline network, by cutting down the time used in calculations. Once the analyzer is set up for a specific problem, the answers can be obtained in about half an hour, where formerly it took days and weeks by trial and error methods.

Typical examples of the varied applications of the analyzer are found in studies such as determination of favorable location for pipelines; selection of pipe diameters for best combination of economy and performance; effects of choice of elevation of reservoirs or storage tanks; and evaluation of pressure variations.

The analyzer utilizes a system of electrical analogies for physical factors involved in networks carrying water, oil and natural gas, as well as steam heating networks and air conditioning systems. An electrical control board is used to duplicate an actual supply network, which can be composed of as many as 99 different supply lines. The operator can also control such factors as source, rate of flow, pressure and other related elements.

Special tubes, known as fluistors, are employed and the amount of light reflected by these lamps indicates the section of pipeline which is under the heaviest load, and the meter readings on the front of the device register other comparative values of pipeline networks. Engineers are thus able to evaluate and interpret the results to determine construction or modification requirements.

Watertight Binding Posts.—Hugh H. Eby, Inc. of Philadelphia, announces a new binding post for use in sealed equipment requiring external connections. Developed to meet government and commercial requirements for rugged portable and vehicular equipment, these posts provide heavy spring pressure for good contact on small soft wire or heavy steel and copper conductors. Contact jaws are of stainless steel; insulators are of teflon; washers of rubber. Rubber caps are available in red or black if desired.

A transonic wind tunnel at the Navy's David Taylor Model Basin, when completed late in 1953, will permit testing of models at speeds up to 900 mph. The tunnel, based on a design partly built by the Germans near Munich, will be of closed circuit type, 574 ft. long. The wind going through this tunnel will be German in origin—a 19-ft. double fan with contra-rotating blades designed and built by German engineers, seized by the Allies in 1945. Included in the project is a cooling tower and air drying system. Construction will be of reinforced concrete, with test section of steel.

A plastic patch for pipes developed at the Naval Damage Control Training Center, Philadelphia, can be applied in seven minutes, will withstand working pressure twenty minutes later. Patching material consists of fibrous glass cloth, resin and activator, and fibrous glass tape. No surface preparation other than wiping dry is required, the patch will work over jagged ruptures or sunflower bursts, will even join two ends of completely severed pipe. The patch is not affected by gases or liquids in shipboard lines, with exception of high temperature material. No outside heat is required in applying the patch.

A new collision warning radar developed by the Navy Bureau of Aeronautics gives a pilot a constant picture of everything within two hundred miles of his plane, whether mountains, other aircraft, or thunder storms. The radar weighs 250 lb. installed, is pressurized for operation at 50,000 ft. Radar signals can be transmitted in a pencil-like beam for obstacle detection and general search, or in a vertical fan for mapping and navigation. Recent test in an Air Force C-97 at 17,000 ft. picked up the Azores at 195 miles, with excellent definition.

Creped Parchment Paper.—As a substitute for textile linings, creped parchment paper is becoming popular in the rubber trade. Its advantages are that the creping adds considerably to its strength and allows of easy separation from tacky surfaces. The paper is generally supplied in rolls about 200 yards long and 38/39 in. wide. The degree of stretch can be varied up to about 70 per cent of the original flat length. The weight of the paper before creping is 2 oz. per square yard.

Sterilshield Cabinets.—Sterilshield Cabinets—dust and germ free work benches—manufactured by The Baker Company of Maplewood, Maine have been completely redesigned and now feature a central air cleaning unit using electrostatic dust collecting equipment and a blower to pressurize up to four workspace sections which may be arranged in any order on either the right or left hand side of the cleaning unit.

The workspace sections 14 gauge stainless, non-magnetic steel formed as a pan for the enclosed bench top, and dual 30 watt fluorescent lamps provide ample illumination for the 24 x 40 bench. Vision is unrestricted thru a plate glass window in the hinged sloping front which may be raised to admit large work.

A completely open front makes it possible to work on the bench without the restriction of gloves, armholes or other limited access ports and a section which slides under the work bench top pulls out and hinges upwards to close the front opening when the unit is not in use. Automatic switches start the cleaning unit and blower whenever any cabinet is open for use, and ultraviolet lamps are added when it is desired to kill airborne bacteria.

Other designs are available for units with exhaust blowers in the rear of the work-space or for other sizes with customers special tools mounted inside. Operation of the unit within any room tends to continuously overhaul the air so that all operations performed nearby will benefit from less dusty conditions.

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Follow the American Tentative Standard Abbreviations for Scientific and Engineering Terms, published by the American Standards Assn.

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1. Photographs
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   (c) Caption for each photograph should be written below the photograph. Captions will be set in type to appear under the figure.
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